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Academical Lectures

ON THE

Theory of PHYSIC.

BEING

A GENUINE TRANSLATION of his

INSTITUTES

AND

EXPLANATORY COMMENT,

Collated and adjusted to each other, as they were
dictated to his STUDENTS at the University
of *Leyden*.

V O L. IV.

Containing the Oeconomy of the External and
Internal Senses, Sleep, and Respiration.

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Of the Touch ' or Feeling.

§.481. **T**HE corporeal Organs with which we are said to examine Bodies by the Touch, are soft, pulp-like nervous *Papillæ* ², *medullary* ³, and of a pyramidal Shape, arising from the subcutaneous Nerves first casting off their exterior Membranes, and render'd very soft; whence they become very sensible, being continually *moistened* ⁴ with a very thin liquor, and defended with a very thin and dense or compact *Cuticle* ⁵, without impairing their Sensibility, lodged under the Cuticle in Furrows and *Cavities* ⁶, and capable of contracting and *erecting* ⁷ themselves in those Parts, where the Sense of *Touch* ⁸ is the most exquisitely performed, as in the Tongue, Ends of the Fingers, &c.

¹ By the Touch in this place, we do not understand that universal Sense, without which there is not any Part of the Body to be found; but we here intend that particular Sense, which is exercised by the Ends of the Fingers, as by a particular Organ or Instrument. Nor yet do we here speak of that Change in our Thoughts, which arises from the Idea of Cold, Roughness, or the like;

2 *Of the Touch or Feeling.* §. 481.

for we cannot determine any thing with Certainty concerning those Changes: But we here intend that Change in the corporeal Organ, from whence arise in the Mind the Ideas of a cold, rough, or moist Body, &c.

² That these are the proper Organ of Touch, is evident from a Destruction or Loss of that Sense, which follows from a Compression, Erosion, or Burning, so as to destroy the Papillæ. If the reticular Body is injured by Fire in the Ends of the Fingers, the Papillæ are destroyed, and the Sense of Touch is abolished. These Papillæ arise from the Nerves, and transmit the Impressions which they receive to the Nerves, and by them to the Brain, where at length the Idea of Touch or Feeling is excited.

³ All the Nerves of the Skin which are destined to the Sense of Touch, have that Sense but in a very dull manner, so long as they are covered with the thick Coats or Integuments; but when those membranous Coverings are deposited, and form the reticular Body, the Nerves are then naked, and of so soft a Texture, that they resemble a Mucus, yet are they in that State the more sensible. Hence we find that not the Meninge, but the Medulla is the Organ of Sensation; for upon opening the Skull of a living Dog, and puncturing the Meninges, no great Disorder is observed in the Animal; whereas if the Medulla itself be injured, the Animal is then immediately convulsed, and staggers.

⁴ This is a great Use of the Perspiration distributed throughout the whole Skin: For neither could the Nerves be supplied with any Moisture, but what has been extravasated; nor yet could the Nerves be capable of performing their respective Senses, if they were not moistened. When the
Skin

§. 481 *Of the Touch or Feeling.* 3

Skin is dry, the Sense of Touch is either depraved or abolished. They who sleep with their Mouth open, are not capable of distinguishing any thing by the Taste in the Morning; for the admitted Air has dried up the Tongue. When the Nose is stuffed up with Dust, the Sense of smelling ceases.

5 If the Nerves were naked, they would not be capable of preserving their Continuity but for a very short Time; and therefore Nature has given them this Defence of the Cuticle, which is a very thin Membrane, that it might not exclude the Impressions of sensible Objects; but very compact or firm, that it might the better defend or secure the soft naked Nerve which lies under it. The Sense of Touch is most perfectly exercised under these Circumstances. The naked Papillæ being gently touched with a Feather, excite an intolerable Itching: nor is there any other Cause of that exquisite Sense and most violent Itching which is observed in the Glans Penis, and in the Female Organs, more than the numerous and thick-set Papillæ. But the Cuticle covers all the naked Nerves, even where the Skin itself is absent. We call the Mouth that Fissure or Division betwixt the Lips, which in the Fœtus is larger than usual, extending itself almost to the Ears in an Embryo of four or five Months old. Hence it is that Infants, who are born after seven Months Gestation, have their Mouth opening wider; whereas those of nine Months have a less and nearer Mouth; for the Fissure is continually and gradually diminished by the conjoining Skin. In the Mouth therefore the Skin terminates at the Lips; whereas the Cuticle, which is extended much farther than the Skin, covers the whole Lips internally. If this thin Cuticle, or Epithelium of *Ruyseb*, is taken off by Maceration and Shaking, the Papillæ remain naked,

ked, and stick out on all Sides like Hairs. If these Papillæ are injured after the Cuticle is exco-riated or vitiated, the worst Maladies follow with intolerable Pains.

⁶ Namely, the Wrinkles of the Skin running variously together, and leaving triangular, quadrangular, or pentagonal Spaces differing in several Parts of the Body. These Sulci or Furrows of the Skin have the Cuticle inflected betwixt them, under which there are placed two Orders of nervous Papillæ. Betwixt these Furrows are seated the exhaling and sudoriferous Vessels, together with the Hairs; all which has been very well observed by *Malpighi*.

⁷ *Malpighi* observed in the Body of a Person, whose Skin was not in the least callous, that after Dinner, in a warm Air, he could perceive by the Microscope in the Ends of the Fingers, a great Number of small round Bodies like Warts (which were the nervous Papillæ) rise up suddenly, when the Person endeavoured, as it were by the Influence of his Will, to examine any thing accurately by the Touch. But in the Tongue this Experiment is more easy and conspicuous; for if a Person stands fasting before a Looking-glass, and a little Sugar is offered to the Tongue to be tasted, you will plainly perceive the whole Surface of the Tongue beset with small Tubercles. Snails furnish us with a notable Instance of this Extension or Protuberance. For when these small Animals go forward, they frequently put out their Horns to search out what Dangers may lie in the Way; their Eyes being also fixed in the Tips of their Horns: but when the timorous Reptile meets with any hard Obstacle, the Horns are immediately retracted. The same Thing takes place in the nervous Papillæ, only it is much less conspicuous.

§. 482. *Of the Touch or Feeling.* 5

^s The Organs of this Sense are the subcutaneous Nerves, which having deposited their Coverings or tough Skins, form with them one continued Integument, whose Vessels are so small, that they cannot be render'd visible by any Inflammation, Injection, or even by the Microscope; but immediately under this Cuticle is spread a softer Substance known by the Name of the reticular Body, which is unequally surfaced, having Furrows which intercept Spaces, in the Cavity whereof are lodged the Papillæ: Nor do the Furrows belong to the Cuticle, but to the reticular Body.

§. 482. But with respect to these Papillæ, it is very remarkable and surprizing, that tho' they are disposed in a perpendicular Position with respect to the Skin in the other Parts of the Body, yet at the Ends of the Fingers and Toes they lie *extended*¹, according to the Length of the Joints; from whence they are continued and folded up in the *Cuticle*² as in Sheaths, in which becoming dry, they are condensed into the Nails; and by means of the consolidated or condensed cutaneous Vessels, serve to *defend*³ the Papillæ, and are *fitted*⁴ to prevent them from growing callous.

¹ We observe first Striæ, which on the outside and lateral Parts of the Ends of the Finges run parallel; but betwixt these Striæ are disposed the Papillæ, not perpendicularly erected, but disposed one over the other in Strata. When these Striæ touch the Nail, there the exterior Papillæ, with the cutaneous Vessels and Cuticle itself, are extended into right Lines, and hardened into the Sub-

6 *Of the Touch or Feeling.* §. 483.

stance of the Nail itself; but the remaining lower Striæ, which are placed under the Nail, go on close together in right Lines, and cover the Nail. But those Papillæ which are continued laterally to form the Nail, diverge and spread themselves on each Side towards the Fingers; upon which they form those spiral Lines, which are peculiar to the Skin in the Fingers Ends.

² To this adhere the Nails; and the Nails separate or come off with that Glove of the Cuticle, which Anatomists take off from the Hands of a Fœtus by Maceration.

³ Under the Nails the naked Papillæ are extremely sensible; and by cutting the Nails too close, they occasion not so much a Pain, as an intolerable Uneasiness in feeling.

⁴ In most Animals there is still another Use of the Nails, of which the human Species are likewise not wholly destitute; for if we neglect our Nails they grow out into long Cones, like unto the Talons of an Eagle, whenever they are allowed to grow on without cutting for a considerable time. Thus it is with the *Chinese*, who suffer their Nails to grow from a Principle of Religion, and for a Mark of Dignity. But in all rapacious Brutes, whether Quadrupedes, Birds, or Insects, the Nails are given as Instruments of Safety for defending themselves, and making War upon others.

§. 483. The Touch then is performed by applying the End of the *Finger* ¹ to the sensible Object which is to be examined, and while the Papillæ are erected or *extended* ² by the Attention of the Mind, by *gently* ³ rubbing them over the Surface of the Object, a certain *Motion*

§. 483. *Of the Touch or Feeling.* 7

tion⁴ is impressed upon those extended Papillæ; the Effect of which is conveyed to the common Sensory, where it excites in the Mind the *Idea*⁵ of *Heat*⁶, Cold, Moisture, Driness, Softness, Hardness, Smoothness, Roughness, Figure, Motion, Rest, *Distance*⁷, *Titillation*⁸, *Itching*⁹ and Pain.

¹ This might be performed as well by the Toes as the Fingers, if we did not continually walk in Shoes, and render the Papillæ callous or insensible by the continued Pressure of the Body.

² At least they are erected when the Mind is attentive, if they are not extended or thrust out.

³ The whole Touch is the Resistance of the Body which we feel. If this Resistance is moderate, the Feeling is distinct; but if violent, a Pain arises in the sensitive Organ: thus when the Cuticle is off from the Finger, we do not distinguish the Qualities of Bodies, but are only sensible of a Pain in the Organ.

⁴ Motion is nothing more than a Change of Surface; but yet the same being conveyed by the contiguous Nerves to the Mind, does there impress its certain and determinate Idea.

⁵ The Organist of *Amersfort*, concerning whom Mr. Boyle writes, that he had so exquisite a Touch that he could distinguish Colours and black Letters by Feeling, when he was fasting, and the Season of the Year not too dry.

⁶ We call a thing warm or tepid, which has the same Degree of Heat with that of the human Body; and hot when the Heat exceeds that of our Body: but that which has a less Heat than our Body is said to be cold. This Sense of Heat is perceived by the whole human Body, but is more

8 *Of the Touch or Feeling.* §. 483.

exquisite in the Ends of the Fingers and Tip of the Tongue ; that is, wherever the nervous Papillæ abound or are most numerous.

⁷ This is a surprising Observation proposed by *Cartesius*. A blind Man or any other Person in the most profound Darkness will be in no Danger of running against hard Bodies, provided the Hands are armed with Sticks crossing each other ; the Ends of which strike against the Bodies or Obstacles to be avoided. From hence it appears, that there is a kind of natural Trigonometry in us, and that our Bodies are taken for the Base of the Triangle, the Sticks for the Sides, and the Mind concludes from the Vicinity of the greater Angle of the Vertex concerning the Nearness of the Body or Object ; and from the Smallness of the same Angle it judges the Object to be more remote.

⁸ For thus we call that State of a Nerve in which it is so far extended, that a small Degree of greater Tension will excite Pain. The Vellication which we perceive from a Feather in the Nose, is not Pain, and yet it is intolerable, insomuch that being continued, the Vellication is communicated to the larger Nerves, and then Convulsions are excited.

⁹ Nothing is more pleasing than this Sense, nor is there any other corporeal Pleasure. It exceeds Titillation in a small Degree of greater Tension in the Nerves, which is such in this Case, that by continuing or a little increasing the Nerve may be broke. It is very well known how severe a Pain follows a violent Itching. In the Itch the Cuticle being elevated leaves a Cavity betwixt itself and the Papillæ, full of an acrid Liquor, with which the Papillæ are stimulated ; and from thence arises such an intolerable Itching, that I have seen some Men faint away by the Excess of Pleasure which
they

§. 484. *Of the Touch or Feeling.* 9

they have from thence received. But if the itching Part is so intolerable from the Sense, that it obliges the Person to scratch with the Nails, a continual Pain follows from a Dissolution of the Nerves. Thus nearly has Nature united Pain to Pleasure.

§ 484. From hence it appears, why we feel *Pain* ¹ by touching an Object after the Cuticle has been abraded by rubbing, macerating, washing or burning? why the Touch or Feeling is destroyed, when the Cuticle is rendered thick, hard and *callous* ², or corrupted by a Scar, what is the Cause of that wonderful Motion of the Body from trembling, and of that disagreeable Numbness, gradually tending to an Insensibility, which arises from the Fish called *Torpedo* ³? why the *Pain* ⁴ is so severe on the inside of the Nail attached to the subjacent Skin, and at the Roots of the Nails? and lastly why the Sense of Touch is most exquisite where the *Nails* ⁵ grow, and where the Sulci or Furrows of the Cuticle are *spiral* ⁶?

¹ Because then the small Nerves or Papillæ being rendered too sensible, are easily destroyed. Such an intolerable Soreness or Incapacity of Feeling we observe after the thin Skin has been abraded from the Lips; and likewise after a Nail has been tore off, and after large Callosities of the Cuticle have been cast off, when the Patient has recovered from an ardent Fever.

² This is no more wonderful than if one should say, that a Hand in a Glove cannot feel with so much Accuracy as if it was naked; for a Callus like

like a Glove prevents the Action of the sensible Object upon the Nerves. The Hand of a tender Girl being pricked with a small Needle, continually bleeds to a considerable Quantity; whereas the same Puncture would not be perceived in the hard Hand of a laborious Man. Hence the Blacksmiths of *Leyden* have such thick Callosities in their Hands, that you may sometimes see them handling the red hot Iron; the Callus at the same Time burning, smoaking, and stinking, and all without any Sense of Pain. But a Callus is a Tumor arising from a Complication of the cutaneous Vessels continually pressed together until they cohere in several Strata.

³ *Aristotle* and *Theophrastus* give us the History of a Fish resembling a Skate, which being touched either by the Hand, a Stick, or even with a Net, stupifies or benums the Sense of Feeling in a Person, and sometimes when the Cause is stronger excites Convulsions. But some of the Moderns esteem these Accounts of the ancient Historians as fabulous; and yet the latest Travellers through both the *Indies* confirm the whole Account. The Theory of this wonderful Phænomenon has been given us by *Borelli*; namely, that there is a very strong and tense Muscle under the whole Skin of this Fish, which contracts when the Fish endeavours to escape from the Thing that touches it, and soon after is swelled or elevated again; both which Motions are performed reciprocally with so much Velocity one after another, as to excite those troublesome Tremors, which even disturbs the common Sensory of any Man: Whereas nothing of this happens when the Fish is dead. To me indeed the whole Affair seems to be no great Difficulty. When a Saw which is very tight and short is sharpened by the File drawn swiftly over it, or if a Glass Ball is cut or sawed

as it were by the Knife, or lastly when a musical Chord very short and tense is moved by the Bow, such an intolerable screaming Noise arises as sets the Teeth on Edge; so that every one would gladly get rid of it at any Price. But yet in this Case nothing more happens than a Tremor in the auditory Nerve, corresponding to the Tremors of the Iron which is filed. By the same Reason therefore when the Torpedo-fish excites most swift Tremors by its Muscles, the Nerves of the Person who touches the stuporiferous Animal are excited into Tremors of the like Nature. Nor is it wonderful that this Effect should be communicated through Sticks, or even through the Nets themselves: For if a long Stick or Pole be suspended by the Teeth, and any Person strikes the Pole at the other End, the Stroke will be perceived as strong in the Head as if it was immediately inflicted upon that Part.

⁴ The Papillæ which lie naked and parallel to each other under the Nails, are continued like Scales over each other, and proceed in that manner in great Numbers to the End of the Finger. If these Papillæ are carelessly exposed by cutting off too much of the Nail, a very acute and troublesome Sensation will arise whenever the Finger touches another Body; which yet is something different from Pain, and gradually goes off as the Nail grows up, and repairs the former Covering of the Papillæ.

⁵ Because there the Papillæ are disposed like Scales or Tiles. When an Inflammation is there seated, a most intense Pain follows, which a prudent Surgeon allays by making an Incision through the Nail, without which the Pain might arise to such a Height, as even to produce Convulsions themselves.

⁶ For here they are more numerous, whereas in other Parts of the Body they are not set so thick together, but lie scattered at greater Distances. To which add, that in the Fingers Ends there are neither Muscles or Fat, but only a Sort of spongy Flesh, throughout which the Papillæ are dispersed in great Numbers.



Of the TASTE.

§. 485. **O**N the Back of the *Tongue*¹, especially towards the Point and Sides thereof, under its *Skin*² lie obtuse Papillæ, which are observed of *three Kinds*³, and which erect themselves apparently in a Tongue that is living, warm, moist and thrust out of the Mouth to taste any sapid Body, more especially when a Person is fasting; but in dead Bodies these Papillæ of the Tongue disappear. They arise from the Nervous Body which lies upon the muscular Flesh of the Tongue, lodged in a kind of fine cellular Membrane, containing a little Fat, from whence they rise up and perforate the reticular Body, directly in the same Manner as we observed before in the Skin; (at §. 417, 418.) they are then confined in erect Capsules or *Cases*⁴ continued from the exterior Membrane of the Tongue, by which they are defended against the Roughness, Acrimony, and Heat of every thing taken into the Mouth. These Vaginæ
or

or Capsules are full of Pores, and *project*⁵ or stick out in such a manner, that the Food or Drink by *Pressure*⁶ acts principally upon them, that they may receive the Impression of the sapid Object.

¹ The principal Office of this small Member is for the Taste, its second Use is to assist in Deglutition, and its third to modulate the Speech ~~or~~ Voice.

² This Name I give to that Integument which is spread upon the Back and Root of the Tongue, upon the middle of which it is thickest, and grows gradually thinner towards the sides and tip, being in all other respects like the Skin itself: but below in the Belly of the Tongue, it is of quite a different Fabric. When this Skin is taken off, which is most easily performed by boiling, the Tongue appears very rough, and beset on all Sides with protuberant Papillæ covered with the reticular Body of *Malpighi*, which receives the Papillæ into its Cavities. At the Mouth or Division of the Lips the Skin terminates as if it was cut off; but then the Cuticle is continued over the Lips, which appear very red from their numerous small Vessels, and which bleed plentifully whenever the Cuticle is peeled off. The same Cuticle continues also to cover the Cheeks internally, together with the Gums even to the Root of the Tongue, where it is continued thin at the Sides; but on the Back of the Tongue it is much like Leather, or callous, and in Thickness almost equal to the eighth Part of an Inch: for in the middle of the Back of the Tongue the Aliments are pressed against the Palate; from whence it is that the Tongue itself and Periostæum of the Palate-Bones become callous by this Pressure and Attrition, which being little or
nothing

nothing upon the lower Part of the Tongue, the Skin is there extremely thin. This thick Integument therefore of the Tongue, also forms the Coverings of the ninth Pair of Nerves.

³ Some conical, others like Mushrooms, and others again inflected like Arches. Those Papillæ which are the largest, most obtuse and hard, are the least numerous, are comprehended in particular Cavities of their own, and are seated at the Root of the Back of the Tongue; while those which are small, slender, and arched, are observed the most numerous; while on the Sides of the Tongue, the Papillæ are disposed in a sort of Medium betwixt the two former.

⁴ The Tongue ought to be sensible for the Taste, and yet not capable of being injured by a slight Violence. Hence it is both furnished with numerous Nerves, and at the same Time defended with very thick Coverings. The covered Papillæ lie concealed like Horns perforating the Pores of a Sponge. Hence a Person is able to swallow Drink almost scalding, namely, by reason of the Thickness of this Covering of the Papillæ.

⁵ The Tongue of a hungry and fasting Person appears beset with rough Tubercles, whenever any Food is offered to his Sight, which can excite the Appetite. But when the Taste is destroyed, and the Person is dead, the Tongue looks smooth; and hence it is that the Papillæ are scarce demonstrable in the anterior Part of a dead Tongue, so that Anatomists usually take the Tongue of an Ox to shew these Papillæ.

⁶ When the Food is pressed too strongly against the Tongue, no Taste arises; but a Person will rightly distinguish the Taste of a sapid Body, by gently pressing it against the Surface of the Tongue, thrust up against the Palate.

§. 486. And it appears probable that these Papillæ, which are so very numerous, arise from the *ninth*¹ Pair of Nerves sent to the Tongue, and distributed through it; but that a Branch of the fifth Pair of Nerves is also sent into the *Muscles*² of the Tongue for its voluntary Motions, distinct from that of the Sense of tasting, as we observe in other Parts.

¹ For this Pair of Nerves belongs only and entirely to the Tongue; whereas the fifth Pair is distributed to various Muscles, and likewise to other Senses; as for Instance, to the Nose.

² No Part of the Body is more nimble or active than the Tongue: It is not loaded with Fat, and yet the adipose Membrane is interposed betwixt the several Strata of its muscular Fibres; but in this adipose or cellular Membrane is the Seat of great Disorders; and thence it is that skilful Surgeons are so much afraid of Injuries of the Tongue, such as Wounds, Contusions, Inflammations, Warts, Biting of it, &c. for these Disorders easily spread through the cellular Membrane, and a Cancer itself follows, which often cannot be removed even by Extirpation.

§. 487. *Bellini* has demonstrated by Experiments diligently and accurately made, that these Papillæ are the Organs to which the sapid Object is applied in order to excite *Taste*¹, to which the other Parts of the Mouth, Tongue, Fauces, and Palate, do not at all conduce; but perhaps those Papillæ which are seated in that Part within-side the Cheeks, where the *grinding Teeth*² of each Jaw meet, may have some Share in the Taste. The

1 The Taste is no where perceived but in the Tip of the Tongue and Parts next adjacent. *Belini* has made the Experiment upon himself with his Mouth open before a Looking-glass, as also upon another Friend being present. He dipped a Pencil-Brush in some strong tasted Juice, as in that of Lemons, dissolved Sugar, Sal Ammoniacum, &c. and applying them successively to the Cheeks, Palate, Gums, and Root of the Tongue, no other Sense arose from thence but that of Coldness or Moisture. He then applied the same Brush to the Tip of the Tongue, and immediately there was always perceived a Sense of Sourness, Sweetness, or Saltiness to the Taste. In the Root of the Tongue there is indeed some Degree of Taste, but more dull. All these Experiments I have likewise repeated upon myself.

2 Ruminating Animals throw up a second time into their Mouth the Food which they swallowed with little Mastication. But that this second Mastication might not be without giving some Pleasure to the Animal, Nature has placed gustatory Papillæ within the Mouth near the grinding Teeth; which Papillæ appear like little Horns in the Cheeks of an Ox, or in the Head of a Sheep after boiling. But these have been also found by *Ruyfch* in the human Cheek after a happy Injection; for after taking off the Cuticle lining the Mouth, he found that there were nervous Papillæ seated near the Emissaries or Mouths of the salival Ducts, which are certainly in some Measure Organs of Taste, though more dull than those of the Tongue. In the Palate there is no Taste at all, notwithstanding almost all People by an epidemical Error make it the Seat of that agreeable Sense of tasting.

§. 488. That Matter in vegetable and animal Substances, from whence Art extracts Salt and Oil either separately or mixed together, is the true Object or Matter of Taste; which Matter therefore is either *Salt*¹, Soap, Oil, or Spirit; and the same is also true with respect to Fossils.

¹ Earth and Water are insipid, nor has Oil any Taste but from some other Principle. For of itself Oil is sweet or insipid and smooth, if it is pure and not mixed with any foreign Matter. But the spirituous Rector which resides in all Oils more or less, gives them some Taste; but if that is removed, there is no manner of Taste left in the Oil. But by the Name of spirituous Rector we here understand that most subtle Part of the Oil, or most attenuated Spirit, which is generally of a strong or pleasant Odour, and whole Force is immensely great in proportion to its Bulk. This is easily demonstrated in Wine, or even in Ale itself; for when these are lately drawn out from the Cask, they are extremely pleasant both to the Smell and Taste; whereas by standing exposed to the Air but for the Space of a few Minutes, they lose their Agreeableness, and become flat or dead without suffering any sensible Loss in their Weight. That Part therefore which is the Principle of Taste is indeed very small, and generally resides in the Salt and spirituous Rector reduced with the Oil into a Soap. See our *Chemistry*, Vol. I. p. 80.

§. 489. Taste therefore is excited when the Object or Matter to be tasted (488.) is *attenuated*¹, and as usually *dissolved*² in the Saliva,
C warmed

warmed ³, in the Mouth and applied to the Tongue by the Motion of the circumjacent Parts of the Mouth; and thus the sapid Particles insinuating through the Pores of the membranous Vaginæ, penetrate to the Surface of the nervous Papillæ which are lodged in these Vaginæ (485.) and which are thus affected, moved, and the impressed Motion conveyed from them to the common Sensory, where it excites an Idea in the Mind of *Saltiness* ⁴, *Acidity* ⁵, *Alcaly* ⁶, *Sweetness* ⁷, *Vinosity* ⁸, Spirituousness, *Bitterness* ⁹, *Spiciness* ¹⁰, Heat or *Pungency* ¹¹, *Roughness* ¹², or else a Taste compounded of these.

¹ Hence the Pleasantness of the Taste is increased by Mastication; and even sapid Bodies themselves have a less Taste, if they are applied upon the Tongue quietly, without any Motion or Pressure against the same.

² Salts taste only when they are dissolved, as *Bellini* observes, and the Tongue tasteth nothing, unless what has been so highly attenuated as to be capable of penetrating through the Pores of the external Coat of the Tongue to the Papillæ.

³ Things which are extremely Cold are not tasted; nor can the Taste be exercised where the Tongue itself is exquisitely cold. Hence we read in the Travels of the Prince *de Radzivile*, that it was observed that every thing lost its Taste upon the Top of the Pike of the Mountain of *Teneriff*; nor did Spirit of Wine itself retain its Strength, but only the oily Wines of *Spain* and *Canary* preserved their Strength uninjured.

⁴ By this Name we understand the Taste of Sea-salt, Sal-gem, or the Salt made from Springs,
which

which Taste we also call muriatic. But in a more general Sense it may be taken to comprehend crystalline Salts of any Kind, not excepting those which are termed essential from Vegetables, as the *Sal Acetosæ*, &c.

⁵ Such an Acidity is tasted in Garden Fruits, in Wine, in Vinegar, Spirit of Sulphur, of Nitre and of Vitriol. For all these are Acids, however widely they may differ among themselves.

⁶ Alcaly may be particularly tasted in putrid Urine, and from thence Salts having such a Taste are termed urinous. Nor yet is there here an urinous Taste in the Salts of the Urine naturally. For if recent Urine be distilled with a moderate Fire, it sends over a mere Water; but if to the same Urine you add any fixed alkaline Salt, the Urine then continually exhales a volatile alkaline Salt. And in the same Manner fixed alkaline Salts mixing with our Saliva in the Mouth, cause a Separation of a volatile alkaline Salt which gives an urinous Taste.

⁷ Of Sweets there are many Kinds, some tasting like Honey, others like Sugar, Manna, Cassia, ripe Garden Fruits, or even Vinegar absorbed into the Pores of corroded Lead, &c.

⁸ There are perhaps a thousand different tasted Wines, and as many Sorts of Ale, all which arise from the spirituous Rectifier mixed with an oily Acid; the Taste of which latter is the same from whatever Vegetable it is produced, provided it is obtained pure and free from Mixture.

⁹ Formerly they called the Taste of Sea-salt also by the Name of bitter; but in our Times the Signification of the Term is altered, and we call those Bitters which taste like Wormwood, Aloes, Bile, Coloquintida, rancid Oils, &c. and such a

bitter Taste also arises from a Solution of Tin and Silver in Spirit of Nitre.

¹⁰ We give the Name of Aromatic or Spiciness to those Vegetables, which by chewing feel hot to the Tongue and exhale a strong Smell. Cinnamon, the principal of Spices, and five hundred more of the aromatic Class, represent a particular Smell to the Mind when they are chewed in the Mouth, even though the Nostrils are shut close; and if the Smell of the same Aromatics is only received through the Nose, they are also in some Measure tasted at the same Time. The same is also true with respect to the Smell of roasted Flesh, which being received by the Nose of a hungry Person, makes the Impression of its Taste. Spices therefore seem to affect the Smell and Taste at the same Time; since being taken by the Mouth they fill the Nose with their Odour, or their Smell being drawn through the Nose also makes the Impression of their Taste in the Mouth.

¹¹ Pungent Substances, as Euphorbium, Capsicum, Onions, Horse-raddish, Mustard, &c. are distinguished from Aromatics, in their being destitute of an agreeable Smell.

¹² Roughness or Austerity is remarkable in Galls, Oak, unripe Oranges, &c. where the Taste is sub-acid and astringent in the Mouth.

§. 490. From hence it is very evident, how the same Object comes to produce different Tastes in People under different *Ages*¹, *Constitutions*², *Diseases*³, or Customs and Sex? and why they often taste of the Thing which was before *applied*⁴ to the Tongue?

Why

Why things of the strongest Taste, long continued are *painful*⁵, as Salt, Spices, Spirits, &c. especially when applied to the *naked*⁶ Nerves, or to the Tongue after it has been excoriated?

Why things agreeable to the Taste are also speedy *Restoratives*⁷?

And lastly, why *Water*⁸, soft *Oil*⁹, and *Earth*¹⁰ without Salt are insipid? See §. 507.

¹ The Smell of Rhenish Wine when it is first poured out, does by its Acrimony, cause the Nose of the new-born Infant to contract and be much affected; whereas the Smell of the same is extremely pleasant to an adult Person. Sugar and other sweet things are most agreeable to Children, but in People who are advanced in Years, they seem to be too clogging and weak: But on the contrary things that are Salt, acrid or spirituous, displease Children, and are very agreeable to adult People; namely, because in tender Children, the gustatory Nerves are very sensible and tender, so that they can bear only things which are of a mild Taste, being too violently affected by such as are acrid: whereas the Nerves of adult People being more callous, are not sufficiently moved by those weak and mild Substances, but only by such as are strong and more pungent.

² Sweets are of pernicious Consequence to hysterical Women; and no wonder, since the Nerves of the Teeth being uncovered from their vitrious Crust, are by nothing more injured than by Sugar, which increases the Pain beyond any thing, even to Convulsions; and for the same Reason Sweets are prejudicial in the Tooth-ach.

³ From Diseases arise surprising Corruptions of the Taste. In chlorotic Girls almost all Tastes are abolished; and therefore they are pleased with things that are acrid and sower, capable of penetrating the redundant Mucus of the Stomach. In those who have the Jaundice, the Bile is deposited together with the Saliva into the Mouth, whence every thing seems to taste bitter, though there is not any Fault in the Food. In leucophlegmatic People there is often an intolerable nauseous Sweetness in the Mouth, almost like that of Saccharum Saturni, which is extremely troublesome and sometimes fatal: whereas the Perception of a salt Taste in the Mouth of those afflicted with the Plague, is a most certain Sign of Health or Recovery. Thus I have been informed, by some of my Friends of great Credit, from *Asia*; that in putrid Diseases the Patient is very desirous of Acids to the great Benefit of Nature; and in the same Disorders we abhor Alcalies and covet Acids.

⁴ Only the Order of taking different Kinds of Food the one after the other, may either add to or greatly diminish the Agreeableness of their Taste. After muriatic Salts an acid and watery Wine is the most agreeable; whereas the same will be displeasing if drank after any thing that contains Honey or Sugar. Some of the Remains of the former sapid Body seem to lodge themselves for a time in the Pores of the membranous Vaginae which cover the Papillæ, until they are expelled and excluded or else amicably mixt with the Particles of the sapid Body, which is last taken into the Mouth.

⁵ It is a remarkable Observation in *Malpighi*, that a certain *Italian*, named *Corbetta*, had the external Covering of the Tongue so thin that it was almost naked. In this unfortunate Person all Sorts
of

of Food which were taken excited Pain, instead of an agreeable Taste; so that none but a Diet of Milk, Flesh-broths or Water could be used without Torment. Thus a Tongue which has been scalded by Water, or burnt by Fire, is not capable of Tasting. It was therefore necessary for a kind of Mucus and Vaginæ or Covering, to be interposed betwixt the sensible Papillæ and the sapid Object to moderate the Sense; nor does Tasting seem capable of being performed, if the Tongue is destitute of these Mediums.

⁶ The most pleasant Wine applied to the naked Nerves, as for Instance, in the Eyes, excites Pain and Tears: And almost the same Effects will it produce in the Nose and upon the Tongue of a tender Infant, when at the same time nothing seems more agreeable to the Tongue of an adult Person.

⁷ The most sapid Bodies are thus instantly restorative, inasmuch as they contain a great deal of the powerful spirituous Rector, which alone gives Taste to insipid Bodies, and is so subtle a Liquor that *Sendivogius* estimates it to be but $\frac{1}{8200}$ Part of the whole Body. Thus from a whole Pound of Cinnamon there are scarce sixty Drops of Oil distilled, and those sixty Drops being diminished but one Grain in Weight, by exposing to the Air, have no Taste. Yet so small a Weight or Portion of that single Grain as is diffused through each Drop of the Oil, is capable of being absorbed by the smallest Veins, and extending to the Blood without losing its Efficacy so as to recruit and invigorate the whole Body. (See §. 67.)

⁸ Water because it does not affect our Senses, if it is weaker than that Moisture which continually supplies the sensitive Organ. Thus we do not perceive the Pulsation of the Heart and Arteries

while we are well, but we are only sensible of it when they vibrate with too great Violence. Hence pure Water seems to be destitute of Taste, because it is less salt than our Saliva; but the Taste of the Saliva never leaves the Tongue, and upon that account it is not perceived. But when once Water begins to have a Taste, it is no longer pure. Things unaccustomed in general affect the Senses so much the more strongly, in proportion as the Objects were used to be more violent. There was a certain *English* Gentleman who by Misfortune was condemned to a subterraneous Prison destitute of all the usual Light: for the first he could not at all distinguish any Object, but afterwards to his Surprise he began to see the Walls, at length he could distinguish his Skin, and at last discern Letters so as to be able to read. From whence it is sufficiently manifest, that the weak Rays of Light now became sensible to the Eye, which being before more callous neglected those faint lucid Rays. Another Instance is related by Mr. *Boyle*, of a Man who was blind from his Birth, and who being couched for a Cataract when he was come to adult Age, did from the unusual and sudden rushing of the Light into his Eyes, perceive a kind of Pleasure and Itching throughout his whole Body, like that in the Act of Venery, with so great a Commotion that he fainted away; which Tenderness of Sight however vanished by Degrees as he grew more accustomed to the Light. *Dionysius* being well aware of this Experiment, in order to torture his Enemies more exquisitely, used to expose them suddenly to the strong Light of the Noon Sun, by opening their Eyelids after they had been kept for a long time in Darkness.

° Fresh Butter well washed in Water is insipid. There is a wonderful Process in *Isaacus Hollandus*,
by

by which a mild and innocent Oil is obtained from human Blood: namely, he distills by a strong Fire that very acrid, ill-tasted and smelling empyreumatic Oil, and that Oil he preparaes in a Vessel, beating it Day and Night with Water, altogether in the same manner as in making Butter; whence all the Saltness went into the Water, and the Oil continued mild, white and insipid, like that of Wax. The great Labour did not deter me from trying the Experiment, which I found to be true.

¹⁰ Because Earth consists of such gross Particles that they cannot pass through the Pores of the nervous Vaginæ, and by that means remain capable of affecting the subjacent Papillæ.



Of the SMELLING.

§. 491. **T**HE broad Nostrils tending upwards from a larger Capacity to a *less*², and being *double*³ or one on each Side, are extremely well adapted to *draw in*⁴ the volatile and odoriferous Particles together with the Air, so as to convey and apply them to the Surface of their Membranes; and this more especially when the Alæ are drawn outward below or *contracted*⁵ above by the united Action of the Constrictores Alarum Nasi, which arise fleshy from the anterior and lower Part of the fourth Bone of the upper Jaw, and are inserted obliquely within the Alæ Narium, sometimes together with the semilunar Muscle of *Eustachius*.

The

¹ The Smelling approaches near to the Seat of Life and of the Mind. Nothing recruits the Strength so suddenly and powerfully as a spirituous Medicine drawn up the Nose: Fainting or Swoonings in hysteric Fits are by nothing so soon removed as by Medicines drawn through the Nose. Nor does any thing so soon excite Diseases as a spirituous and virulent Matter of a Nature foreign to our Bodies.

² The Nostrils contract or grow smaller upward, and diminish in such a Manner that at their Termination in the Region above the Palate, their Opening is scarce thicker than one's Nail. Hence it happens that they may be easily closed, and, like a converging or conical Tube growing narrower, affect the Nerves with a stronger sense of Smelling. Hence it happens that when the pituitary Membrane is swelled, as it frequently is in a Cold, the continual Passage of the Air through the Nostrils is then intercepted, the Smelling ceases, and the Breath of the Person sleeping can be only drawn through the Mouth. This Narrowness of the Passage through the Nostrils is a Caution of Nature to prevent volatile Insects, Dust, Poisons, &c. from being drawn through the open Nostrils into the Lungs, so as to suffocate the unwary Animal; for thus they are either repelled by the Narrowness of the Passages, or else they are resisted by the opposite Mucus or Hairs, 'till at length they are cast out by the Force of Sneezing.

³ The anterior Part of the Nose is formed with a Cartilage that it might easily bend without breaking. But the Cartilages are covered with the same olfactory Membrane as invests the Bones of the Nose.

⁴ When the Ribs are elevated and the Cavity of the Thorax dilated, the Air filled with odorous Particles

Particles rushes violently through the Nose into the Cavity of the Lungs, in which there is made an imperfect Vacuum. But that the Thorax is a Machine adapted to form a Vacuum is easily demonstrable. For thus the most strong smelling Bodies are excluded from our Sensation when we hold our Breath, nor can even the Smell of Spiritus Salis Ammoniaci itself affect the Nose but when the Air is inspired or drawn into the Lungs.

⁵ For in that State by the Force of the inspired Air, and the Force of the constrictor Muscles of *Eustachius*, the odoriferous Particles are applied to the sensible Membranes of the Nose. We use this organical Action of the Muscles, when we endeavour to accurately distinguish any faint Smell.

§. 492. But the Cavity of the external and internal Nose includes all that Space into which open, 1. The *frontal Sinus*'s which are generally formed betwixt the two Tables of the Os Frontis, removed from each other under a Protuberance beneath the Eye-lids, from whence they open by a Foramen above into the Cavity of the Nostrils, near the upper Part of the Offa Nasi; they are lined internally with a mucous Membrane of the Nose, which is spread all over the internal Surface of their Cavities, where the Mucus being formed, distills from thence into the Cavity of the Nose. 2. The *Antra Higmoreana*, which are large and seated in the upper Jaw opening with a large Aperture into the Cavities of the Nostrils; and these likewise receive the same Membrane, and serve to separate, collect and discharge

discharge the Mucus into the Cavity of the Nose. 3. The small Cells of the Os Cuneiforme under the Os Spongiosum, opening by several distinct Perforations into the Cavity of the Nostrils; which Cells also receive the mucous Membrane of the Nose, which lining them separates, and that way discharges the Mucus,

* These frontal Sinus's are found very large when the Smelling is more perfect than usual. In hunting Dogs they are very small, but very large in Setters, or those which take the Scent. In those who have their Nose very flat or depressed, and the frontal Sinus's absent, in them the Sense of Smelling is either absent or less than usual. Nor are these Sinus's to be found in the Foetus. For all the Organs of Sense lie idle in the unborn Infant, and are defended from all the Impressions of external Objects. The Ear is closed or stopped up, that the Infant may not be startled by any violent Sound: the Humours of the Eyes are turbid or opake, insomuch that one would imagine that new born Infants were blind if the Humours did not recover their Clearness and limpid State in a few Days time; and this Opacity of the Humours in the Eyes of young Brutes is still greater. In the same manner also Nature has not given the Foetus any of the pituitary Sinus's, that it might be sensible of Smells. But when as Age advances, the Diploe is augmented betwixt the Tables of the Cranium, these Sinus's are then left betwixt them. And in the same manner as Age advances, and the Head grows larger, the maxillary Sinus's are formed. It is the Absence of these Sinus's which occasions the Noses of young Children to be perpetually running with Mucus; for they are the Receptacles of the Mucus, with
which

which being filled, it is afterwards returned from them or regurgitated from the Antra. These Cavities are larger in the Adult, and are capable of holding almost an Ounce of Liquor: they are not therefore formed by Nature to no Purpose, but with a View of increasing the Surface of the pituitary Membrane for the more perfect Performance of the Smelling; and I am very apt to believe, that if this Membrane, could be taken out from all those Cavities uninjured, it would appear twenty times as large as the external Nose.

§. 493. Besides these, in the Cavity of the Nostrils are concealed and artificially disposed in different Parts four small spongy Bones called the *Ossa Spongiosa* ¹ of the Nose, two in each Nostril or Cavity of the internal Nose; the one of these two Pair of spongy Bones is connected above and before to the upper Part of the Jaw-bone, where it unites to the Apophysis of the Os Frontis, at the internal Angle of the Eye; the other is fastened in the lower Part of the Cavity of the Nose to the upper Jaw-bone itself. These four small Bones are wonderfully framed of very thin Plates or Lamellæ thinner than Paper, but so convoluted or folded up together, that they form a great many hollow Cavities, within which the pituitary Membrane insinuates itself, so as to pass in and out from those little Caverns, and accurately invest the whole Surface betwixt the Lamellæ, and leave a free Space or open Cavity betwixt them. The Cavities of these thin Bones and of all their smaller Cells, have
a free

a free and open Communication into the Cavity of the Nose.

1 The *Ossa Spongiosa* are accurately placed against that Part of the Nostrils where they are narrowest. But they are composed of Leaves folded together as thin as Paper, more especially in Animals of exquisite Smell; and in some Animals where this Bone takes the Name of *Turbinatum* from its many Convolutions, there are at least thirty *Lamellæ*, each of which are covered with their olfactory Membrane, which may be best freed from the Bone in order to prepare and preserve it by placing it in a Box full of Holes in the midst of an Ant-hill. Thus there are sixty plain Sides or Surfaces of this Membrane, each equal to its bony *Lamellæ*. But it is manifest by these Means the Sense of Smelling becomes greatly increased, though it would be otherwise dull.

§. 494. The external and internal Nose composed of Bones, Cartilages, and Membranes, are invested or lined with a *thick* 1 and soft mucous Membrane, adorned with Myriads of small arterial *Vessels* 2, and furnished with round glandular *Corpuscles* 3 together with very small Vessels which distill a *thin* 4 Lymph into the Cavity of the Nostrils; and under that Membrane is spread the *Periosteum* and *Perichondrium*, which is a very thin nervous and vascular Membrane. Both these Membranes conjoining strictly together, insinuate themselves into the Cavities of the six Sinus's before-mentioned (§. 492.) and into the Cells of the four *Ossa Spongiosa* (§. 493.); so that by a wonder-

wonderful Contrivance, this Membrane is expanded into a very large Surface, within the narrow Compass of the Cavity of the internal Nose; but they are disposed so as not to hinder the Use of each other.

¹ Its Thickness arises in a great measure from the many Cryptæ and large Quantity of Mucus; for of itself this Membrane is so thin that it scarce equals the tenth Part of the Thickness of a Sheet of Paper.

² *Ruyfch* having injected Wax by the crural Artery in a Foetus with great Artifice, found that the injected Matter escaped through the Nose, in the same Manner as if it had bled, which is a manifest Sign that the Arteries open themselves in this Part; and therefore it is no wonder that by violently blowing the Nose, Blood should be sometimes forced out. In Oxen, Sheep and other Animals who have a long Nose continued from their Eyes forward, in order for them to more accurately distinguish poisonous from salutary Herbs by the Sense of Smell; in such Animals these muciferous Arteries run forward in a Parallel Course, and discharge a lymphatic Juice with which the whole Membrane is moistened: But these excretory Ducts being obstructed the Arteries swell, the Nostrils are stopped up and the Smelling ceases, as we observe in the Disorder which we call a Cold.

³ Such glandular Corpuscles are admitted even by *Ruyfch*, though he calls them by a somewhat different Name, to wit Cryptæ. In a healthy Person who has lately expired by a violent Death, upon opening the Head and pressing the Membrane of the Nose, it discharges a pellucid Liquor readily congealing into Scales, which seems to issue
from

from many small spherical Points. With such a pellucid Humour or one not much different, the Eyes themselves are moistened, which Humour soon congeals into a white Liniment if it is not wiped off. With the Mucus of these Glands the tender Nerves are defended.

⁴ The Mucus soon after Secretion is not thick or like a Liniment, but becomes of that Consistence by standing in the Cryptæ or Cells of the Membrane; and at length only by standing or exhaling its more watery Part by Fire it concretes into hard and tough Scales. When it becomes inconvenient or uneasy by standing too long in the Nose, or being collected in too large a Quantity, it is then usually discharged by Sneezing; and hence it is that healthy People usually discharge the accumulated Mucus by Sneezing as soon as they rise in the Morning. But in old People and in Children the Heat does not so much dissipate the thinner Parts of this Mucus, and therefore in the Winter-time they have a Dripping at the Nose.

§. 495. The olfactory Nerves passing *without* ¹ the Dura Mater to the Os Ethnoides, transmit their tender Fibres through the small *Foramina* ² which we observe in that Bone, and which are lined with Productions of the Dura Mater; through these Foramina the nervous Fibres pass out of the Os Cribriformæ and are immediately distributed throughout the large Surface of the Offa Spongiosa (§. 494.) into all the Sinus's and Cells (§. 492, 493.) in an accurate Manner.

That

¹ That is, the soft pulpy Substance of the Brain itself being continued to the Os Cribriforme, passes through the Foramina of the same Bone, which are invested with the Dura Mater, into the Nose, where they are expanded in the Form of a Membrane ; so that within our Noses the naked Substance of the Brain itself lies exposed. This is the Reason why the Ancients would not venture to give them the Name of Nerves, but called them mammillary Processes. In brute Animals even the Ventricles of the Brain itself continue their Cavities forward with the olfactory Nerves into the Nose, in such a manner that one may inflate them like Tubes, and even distend the whole Brain itself by blowing through them. For in these Creatures Nature has furnished them with nothing more than an exquisite Sense of Smelling, in order to chuse out their Food. If a thousand different Herbs are given to an Ox or a Sheep in an Armful of Grass, they will by their Noses distinguish and pick out from all the rest, that which may be taken as Food without Injury.

² These Foramina are apparent enough in the Skeleton, but in the recent Body they are almost quite closed up : for the Dura Mater fills every one of these Foramina, and is continued through them like a Funnel ; each of these little Funnels being filled with its proper Branch of the olfactory Nerves, which are a Continuation of the Brain itself. But by the Interposition of the Processus Crista Galli the soft olfactory Nerve is defended from being injured by the incumbent Mass of the Brain.

§. 496. From hence it appears that the Expansion of these Nerves is very *large* ; nor are there any Nerves throughout the whole

Body so *soft* ² and naked, and therefore they are more apt to be easily affected and injured in this Organ of Sensation.

¹ The optic Nerve is expanded into the Retina, and the auditory Nerve into the Membrane of the Labyrinth, the gustatory Nerve into the Tip and Part of the Side of the Tongue; but the olfactory Nerve has an Expansion even as large as that of the pituitary Membrane itself of *Schneiderus*.

² There are many Properties or Affections of Bodies, which are no way discoverable but by the Sense of Smelling. Sugar is pleasant to the Taste, does not injure the Eyes, or any other of the Senses; but the same being applied to the naked Nerve of the first Pair for smelling, or being applied to the naked Nerve of a Tooth, excites so severe a Pain, as almost occasions Convulsions. As these Nerves are so tender in their Expansion, it was necessary for them to be well defended from external Injuries, lest they should be soon destroyed by Attrition, or become insensible by contracting a Callosity. It is well known how small a Force will destroy the Sense of Smelling; as for Instance, by walking against the Wind, &c.

§. 497. Therefore in all the numerous *Glands* of this Membrane, as also from the numerous arterial Vessels, which are so plentifully distributed in little Fasciculi or Bundles, there is continually separated and discharged a soft or insipid Fluid and inodorous Humour, almost without Colour or the least Brackishness, which lubricates, moistens, and defends the Nerves (§. 496.) on all Sides, and in all their

their Expansions throughout the several Cavities before described (§. 492.) This same Humour stagnating without Motion, and collected in a warm Place, through which the Air freely passes, becomes continually *thicker* ; and is discharged under the Name of Mucus in all Postures of the Body; the Use of which Mucus is to preserve these very tender and naked Nerves in their natural and sound State for many Years, which could not be effected otherwise.

• To preserve these Nerves sensible, and at the same time defend them from being too easily injured, Nature has used a two-fold Precaution :
 1. By continually distilling a thin limpid Humour by small Vessels continued like a Navel from each of the numerous *Cryptæ* : which Humour being insipid in healthy People, is yet brackish in Disorders, and in those who have a Running at the Nose ; and being diffused throughout the whole pituitary Membrane, it often thickens like a Liment. 2. By a limpid Humour, like the former, insipid or but very little brackish, which distils immediately from the open Ducts of the parallel Arteries, distributed through the Membrane of *Schneiderus*, without the Intervention of any *Cryptæ* or Cells ; so that meeting with no Confinement it is discharged quite thin and watery. These exhaling Arteries have been demonstrated by *Ruyfch* by a Method which is not difficult to imitate. Let one of the carotid and both of the vertebral Arteries be tied in some Animal, and inject Water by the other carotid, and the Liquor will immediately distil through the Nose. This Liquor appears to continually discharge itself

while the Animal lives; for if you carefully dry up the Mucus of the Nose, it will in a little time after appear moistened again with the same. It is from these last Ducts continued immediately from the Arteries, that Blood is so easily discharged at the Nose by any violent Irritation.

² Namely, the same liquid Mucus retained in the Sinus's of the Os Frontis, Sphenoides, and upper Jaw, becomes inspissated into a thicker Mucus, which is conveyed into the Nose by different Postures of Body according as the Sinus's themselves are situated. It discharges itself from the left maxillary Sinus, when a Person lies with his Head on the right Side, and the Reverse; from the frontal Sinus it distils while the Head is retained in a perpendicular Posture, and from the Sinus sphenoidalis when the Head is inclined forward. Thus the Mucus distilling from all these Sinus's defends all the naked Nerves, and preserves them from too great Irritation, in the same Manner as Pictures are covered over with a Varnish made of the white of an Egg, to preserve the Colours from being altered by the Air. The Name of an Excrement is therefore very improperly given to so useful a Liquer.

§. 498. But lest this Humour should stagnate too long in its Cavities, so as to thicken and change into a *tophous*¹ Matter, incapable of being afterwards discharged by the narrow Passages of those Receptacles; therefore a Branch of the Nerve of the *fifth Pair*² uniting with the Nerve of the sixth Pair, is distributed throughout the same Membrane; and these being irritated, affect the Par vagum and intercostal Nerves, subservient to the Muscles

Muscles of the Respiration, whence the Mucus is *absterged* ³ and forcibly expelled by the Impulse of the Air, violently forced through the Nose in *sneezing* ⁴.

¹ This Mucus when dried, readily concretes into Scales, and afterwards hardens into a Chalky Matter, more especially when the inspired Air is very dry and full of Dust. But this Mucus also hardens into a scaly Substance, when it has been taken out of the Body, and dried in a clean Glass. From these Causes may arise that troublesome Disorder in the pituitary Sinus's, which we call a Polypus in the Nose; for there is no other true Cause of this Disorder, so frequent as this before-mentioned, namely, such an Inspissation of the Mucus, that it cannot be evacuated; whence it happens that new Mucus being continually accumulated while nothing is discharged, the whole Sinus is at length filled, the Cryptæ and Membranes of the Vessels are obstructed, and by that means the latter is distended so as to protrude itself into the Cavity of the Nostrils, and intercept the Passage of the Air, so that it might be often seen pendulous in the Fauces like a Lump of Flesh. This Mucus being also corrupted, produces an Ulcer termed an Ozæna, which corrodes the adjacent Bones.

² This Nerve sends off a large Branch from the Cavity of the Orbit to the Nose, where it is distributed throughout the whole Membrane of *Schneiderus*, however largely that is expanded in the Nose. These Nerves of the fifth Pair are very naked and easily irritated, since by touching them only with Sugar they excite sneezing, which is a convulsive Motion. Even in the Apoplexy itself,

when the Body lies like a dead Trunk without Sense and Motion, Sneezing may be excited only by irritating the Nose with a Feather. Every thing therefore which irritates or injures these Nerves, will continually vellicate the communicating Nerves of the eighth Pair with the Intercostals and Recurrents; whence the Diaphragm, Abdomen, and all the Organs of Respiration will be suddenly contracted, and expel the Air from the Lungs with a great Force. From this Torrent of Air rushing through the Nose and into the Sinus's, arises that uneasy Sensation which is excited in the sensible Membrane of the Nose at the Time of sneezing, which is performed after the Manner next described.

⁴ Namely, by retaining as large a Quantity of Air as possible, and then by suddenly discharging the same with a considerable Force, with a sort of convulsive Motion throughout almost all the Muscles in the Body. The Use of this Action is to cleanse the Organs of Smelling. It commonly happens in a Morning as soon as we rise; for the Mucus which has been collected all Night without being evacuated, fills the Sinus's, and loads the Membrane so much, that in a Morning our Sense of smelling is either much diminished, or quite abolished. At that Time therefore sneezing is more frequently performed by the Consent or good Advice of Nature, for the Benefit of the whole Machine: Hence Water is first discharged, and soon after the Mucus itself which adheres to the Sides of the Membranes, so as to facilitate the Respiration and recover the Sense of smelling, or render it more exquisite. Physic, in Imitation of Nature, has found nothing more serviceable for an inveterate Stoppage of the Nose, or an incipient Polypus,

Polypus, than the snuffing up of warm Water, and expelling it afterwards by sneezing.

³ When we expose ourselves to the cold Air of an Evening and sneeze, we understand that the next Day we shall be troubled with a Cold, or a Stoppage of the Nose. They who are afflicted with an ardent Fever, ad sneeze towards the latter End of the third Day, generally escape from the Disease.

§. 499. But such *Parts* ¹ of animal, vegetable and mineral Substances become the Object of smelling, as are *spirituous* ², oily, saline, or saponaceous, and so attenuated or divided, that they are capable of floating in the Air: but it is evident from numerous Experiments, that the *subtle* ³ Matter which we call Spirit, residing in the Oil, is more especially that which excites the Smell; for that being perfectly *separated* ⁴ from odorous Bodies, what remains has little or no Smell, and the same Matter being poured upon other Substances communicates a Smell to them.

¹ Such are Oils converted into Spirit by Fermentation, as in Vinegar and Spirit of Wine, the volatile alkaline Salts of Animals, mineral, acid, and sulphureous Spirits, except Oil of Vitriol, which is inodorous.

² The Name of Spirit is given by the Chemists to that subtle Matter lodged in the Oil, salt and saponaceous Part of fossil, animal and vegetable Substances, which is so volatile as to fly off spontaneously from the Oil and Salt, and affect the Nose; and this is the only Matter of Odours: for an odorous Body, whether pleasing or displeasing,

ing, has no longer any Smell when once it is deprived of its spirituous, oily and volatile saline Parts. Nor does the fixed Salt or the Water, nor even the Oil itself, contain any Smell when deprived of this Spirit. Also the volatile alkaline Salt has not any Smell but from this spirituous Rector; which is therefore the true Object or Matter of Smells. But the oily Parts are in some measure subservient to this Sense, since they fly off together with the spirituous Rector, and adhering to the Surface of the olfactory Membrane, render the Effect or Action of the odoriferous Particles more permanent and lasting.

³ This is so subtle, that it even escapes the Imagination. A Rose fills a whole Chamber with its most fragrant Smell; whereas if the same be bruised betwixt the Fingers, it smells watery and disagreeable; nor yet will it retain any thing of its Smell, if it lies by for the Space of twenty-four Hours. The same Rose being committed to Distillation in a close Vessel, affords so small a Quantity of an Oil, that from an hundred Pounds of Roses, scarce a few Drops of the precious Oil is obtained, which must be at least ten times more valuable than Gold. Lastly, this so dear and scarce Oil becomes itself inodorous, only by exhaling an insensible Portion or Weight of its spirituous Rector, as we said before concerning the Oil of Cinnamon.

⁴ So soon as that volatile and very subtle Spirit is removed from the odorous Body, all that then remains is more gross, and rather excites Pain and Sneezing than an agreeable Smell.

§. 500. If the Aspera arteria or Windpipe be divided, and the Animal breathes through
the

the open Wound, there will be *no* ¹ Smell perceived even from the Strongest Objects.

¹ Take two Dogs, and in the one, after dividing the Skin, make an opening by Incision into the Trachea or Wind-pipe, and the Lips of the Wound being dilated or drawn from each other, all the Passage of the Air through the Nose and Mouth will then cease, and the Animal will perspire only through the lower Part of the Wind-pipe. If now Spirit of Sal Armoniac made with quick Lime be held to the Nose of such a quick smelling Animal, he will afford no Signs of perceiving any such Smell; but if the same Spirit be applied to the Nose of another Dog, it will excite Convulsions in a surprising manner.

§. 501. When the Air is *expelled* ¹ from the Lungs through the Nostrils, there is no Smell of any external Object perceived.

§. 502. Nor is any Smell perceived while the Breath is held.

¹ The same Spirit of Sal Armoniac being applied to the Nose, will not at all affect us, so long as we either only breath out the Air, or do not draw it into the Lungs through the Nose. When we walk through a stinking Place, there is not a better Remedy to avoid the displeasing Smell, than that of holding the Breath. The Smell, therefore of any thing cannot be perceived, unless the Air by its Weight rushes into the dilated Lungs, by the imperfect Vacuum made by the Muscles which dilate the Thorax, and at the same time carries with itself the Effluvia through the Nose, which it receives from the odoriferous Body.

§. 503. For the Smelling is performed at the time when the Breath is drawn through the Nostrils.

§. 504. And the *stronger*¹ and more frequent the Respiration is made, the more powerfully is the Organ of Smelling affected.

¹ The quick-scented Hound in chasing any Animal by the Scent, applies only his Nose to the Ground, and by a swift Motion of the Ribs breathing alternately, suddenly distends his Lungs with Air like a Pair of Bellows, and expels the same again. By this means the Air is indeed drawn by repeated Inspirations through the Nose without being admitted into the Lungs, by reason of the Expiration which immediately follows; and thus being admitted only to the Nose, conveys all the odorous Effluvia, which it contains, to the Organ of Smelling.

§. 505. The Smell of odoriferous Objects is increased by *Motion*¹, Heat, Attrition, and *Mixture*² of different Bodies; as also by a careful Mixture of Salts with odorous *Oils*³.

¹ Some Bodies only emit a grateful Smell by Warmth and Attrition, as Amber, Lignum Aloes, &c.

² For by Mixture of Sal Ammoniacum with an alkaline Salt, both of which are of themselves inodorous, they nevertheless at the Instant of mixing exhale a most intense Smell. If salt of Tartar be applied to the Nose, at the Instant when it is taken out of the Fire, it has no Smell; but if you breathe upon it, it immediately exhales the Smell
of

of an Alcaly. If a Grain of fixed Salt be taken into the Mouth, it gives the Taste of burning without affording any Smell; but so soon as it mixes with our Saliva, it affords an urinous or foetid Smell; inasmuch as the fixed Salt of Tartar combines with the Acid of the Saliva, and sets at liberty the volatile Alcaly, which exhales and discharges itself by that Means.

³ The aromatic and fragrant Odours of Bodies mixed with Acids, as for Instance, with the Juice of Citrons, increase their odorous Virtue, whereas by mixing with Alcalies their Smell is diminished. The *Italians*, who are most famous and curious in Perfumes, always use mild Acids, as for Instance, in preparing their Gloves, which always smell of something acid together with Ambergrease.

§. 506. The Sense of Smelling is therefore performed while the odorous Effluvia contained in the Air, are by the Motion of Inspiration and the Figure of the Nose, with the Position of the spongy Bones so strongly impressed or applied to the small Fibres of the olfactory Nerves, that by their Action an Idea is communicated and excited in the common Sensory, either of an *acid*¹, alkaline, aromatic, putrid, *vinous*², or other more compound Odor.

¹ The Fumes of Vinegar excite a Sense of Acidity in the Nose, and likewise communicate the same kind of Taste to the Tongue; for an Acid is perceived by the Organs of Smelling if it is volatile, otherwise it is only sensible to the Taste. Thus Oil of Vitriol while cold does not affect the Nose, but is only sensible to the Tongue; but
when

when attenuated and rendered volatile by Fire, it smells violently acid.

² All sorts of Ale, Wine, and Liquors prepared by Fermentation, from whence inflammable Spirits are distilled, afford this vinous Smell.

³ Innumerable are the other sorts of Smells which are hardly reducible to any Classes, as Ambergrease, &c.

§. 507. From hence we may be able to understand the great Affinity or Relation there is betwixt Smells and *Tastes* ¹, or betwixt the Objects of Tasting and Smelling?

Why Smells frequently restore a Person to *Life* ² in a Moment?

By what *Means* ³ *Diseases* ⁴ and *Death* ⁵, with almost every kind of Operation proper to Medicines and Poisons, are sometimes produced by Smells; how the same Smell in *different* ⁶ People comes to produce different and even opposite Effects?

Why Animals which have a *very long* ⁷ Beak or Nose, with very large *Offa Spongiosa*, as *Birds* ⁸, have a more exquisite Sense of Smelling?

What are the very minute *exhaling* ⁹ Corpuscles, which are capable of exciting a copious and strong Smell for so long a time without any sensible Diminution in the Weight of the Object or Body.

By what Means a *fætid Smell* ¹⁰ exhaling from the putrefied Parts of Animals and Vegetables so obstinately adheres and excites a disagreeable Sense in the Nose for a long time after it has been perceived? Whe-

Whether the strongest Smells are not *Sternutatories* ¹¹ ?

Of what *Use* ¹² is the Humour and Mucus which is continually formed and distributed throughout the Membranes of the Nose ?

Why the Sense of Smelling is *dull* ¹³ as soon as a Person awakes, but becomes more *acute* ¹⁴ after Sneezing ?

Whether this mucous Humour serves to purge the *Brain* ¹⁵ ? and how far that is true ?

Whether or no the Mucus is thick at its first Formation ? or whether it becomes so afterwards ?

From whence arises the intimate Consent or *Communication* ¹⁶ betwixt the internal Nose and Muscles of Respiration, together with the abdominal Viscera ?

Whether Sneezing is not a Convulsion, and upon that Account so tiresome or fatiguing, often creating Pains and sometimes proving *fatal* ¹⁷ ? though in the mean Time it excites or increases the Motion of the Brain, Spirits, and all the Humours ? Why Sneezing frequently happens in a Morning after Sleep ? And to what People it is of *service* ¹⁸ ?

¹ There is a wonderful Analogy betwixt these Senses, nor are there any two more nearly related : namely, the same spirituous Rector is the Object both of the Smell and Taste ; only there is this Difference, that that which is the proper Object of Smell naturally exhales in a volatile State, but that which produces Taste is less volatile. Thus roasted Meat fills the Nose of a hungry Person,
not

not only with its Smell, but also impresses the Taste upon the Tongue so long as it fumes; but when it is once cold, it only affects the Taste. For the Organs of these two Senses are very near to each other, since the olfactory Membrane of *Schneiderus* is continued from the Nose to the Tongue, notwithstanding the Nerves, some of which are for the Sense of Smelling, and others for the Organ of Taste, seem to be at a considerable Distance. But there are other Instances, where the Taste of a Body being removed, carries off likewise the Smell. Thus it is in Cinnamon after its Oil has been extracted; for it then remains incapable of exciting either Smell or Taste, like a dry Coal; and in the same manner the Oil of Cinnamon, which has exhaled its most subtle Part or spirituous Rector, loses both its Smell and Taste.

² The Nerves here are exceeding tender, very near unto the Brain, and admit only of the most subtle Parts of Bodies. Even the Medulla of the Brain itself seems to be expanded in the Nose; since the mammillary Processes are not truly like other Nerves. The Person who has fainted away, is not affected by the most high-flavour'd Substances applied to the Tongue, nor does he regard the most vivid Rays of Light, nor yet the strongest Noises thunder'd into his Ears. But if to the Nose of the same Person is applied Vinegar, or Spirit of Sal Armoniac prepared with Quick-lime, he will be roused up with a Convulsion of the whole Body.

³ *Pecklin* in his Treatise *De purgantibus* has demonstrated by accurate Experiments, that all the Force of purging Medicines does not reside in their Bulk or Mass, but in their spirituous Rector. Hellebore when it is just dug out of the Ground
smells

smells dangerously, and the attracted Vapours affect the whole Body by purging, as I have experienced; but by keeping only, it becomes milder by exhaling that nauseous Vapour, so that at length it becomes an useful Medicine. The strong purging Faculty of *Coloquintida* consists in its odorous Particles, which are very small in Quantity; for when that Drug has lost its Smell, it becomes quite inactive. The Root of *Jalap* lately pulverized has a nauseous Smell, and either vomits or purges. Even in the Glass of Antimony, the Matter which excites vomiting is an inconceivable small Part, which being expelled or exhausted, leaves an inactive Mass. In the making of the *Emplastrum de Hioscyamo Michaeli*, the exhaling Vapours while it is boiling being drawn into the Lungs, cause Faintings. The poisonous Force therefore of Medicines seems also to reside in their spirituous Rector.

⁴ Some Women continually faint away with barely the Smell of Musk or Ambergrease; and are revived again by Foetids, which is an Observation of *Aretæus* of old. The same fragrant smelling Perfumes increase epileptic Fits, which the most foetid Bodies mitigate; putrefied Bodies create Sickness and Vomiting only by their continual Smell. The Fumes of burning Sulphur breathed in large Quantities, either kills the Patient, or greatly endangers his Life. Even the adjacent Brain itself seems to be affected by Smells, upon the State of which Viscus the Welfare and Strength of the whole Body entirely depends.

⁵ We frequently read in History of Persons killed by Smells in the Courts of Princes. The Fumes of fermenting Wine, however innocent they may be imagined, are a most speedy and dreadful Poison, from whence Madness or a fatal Apoplexy follows.

follows: If a Person smells to Wine, he will be intoxicated from thence as if he had drank a much larger Quantity; and the like Effect follows from the Fumes of Spirit of Wine. They who handle Saffron in their Hands for a considerable time, become sleepy and often apoplectic. From the Smell of Opium long continued, arises Sleep in the same Manner as if its Juice had been drank. I lately read a wonderful History relating to the Efficacy of Odours. Two Mountebanks contending for the Preference of their Orvietan, had a Promise from the Magistrate of a License or Privilege to him, whose Antidote appeared by Experiment to perform the most. The Trial was therefore begun by taking Poisons themselves. The first Day each took the Poison from his Adversary, and each used his particular Orvietan or Antidote; nor did the one or the other suffer any Injury. On the next Day when they returned to their former Calling, without any manifest Hurt, the one told his Adversary that he could not any longer contend with him, for he had some Kinds of Poison which resisted the Efficacy of any Antidote; but the other intrepidly denied the Fact. A Drum was therefore brought which was continually beat with Sticks, and his Adversary ordered to draw Air from thence through his Nose, to which he rashly consented, and immediately perished: for his more crafty Enemy had included Toads and Vipers in the Drum, which being put into a Rage by the beating and trembling of the Drum, breathed out a poisonous Vapour, which immediately exerted its Virulence upon the Seat of Life itself; namely, the Brain. For the Heart itself, however necessary to Life, is yet rather a ministerial or a subservient Viscus to the Encephalon.

6 In some People there seems to be a particular Disposition of the common Sensory and nervous System, by which they are violently affected by some things which are easily tolerable to others. *Syddenham* in his excellent Epistle *de morbo hypochondriaco* well observes, that there is internally concealed a mere spirituous or nervous Man which governs the whole Machine ; so that we need not wonder that a Motion in one Nerve should excite a Motion in the rest. Some People have been killed by being shut up with Apples, others by smelling at Roses ; an Instance of which I read in a certain Cardinal, and in a celebrated Physician at *Paris*, who fainted away by the grateful Odor of a white Rose. Others have had the Head-ach from smelling at Tuberoses or Jonquils, whereas the Generality of People are not at all injured by these Smells.

7 There is here nothing strange, or to be wondered at : for the Surface of the Membranes is thus increased, upon which the olfactory Nerves are dispersed ; and therefore the Power of Smelling is thus likewise increased. If there is but one odorous Particle of Cinnamon in the Compass of one square Inch of Air, only that Person will smell the Cinnamon, whose Nose happens to catch that one Particle : but such a Particle must be more easily caught by an Organ of Smelling which has a large Surface ; whereas it will be more liable to escape, and more difficultly perceived if the Organ was small. But the larger the Organ of smelling in the Animal, so much the more easily do they perceive Smells ; and the longer the Nose or the more complicated or numerous the Lamellæ of the *Ossa Turbinata*, the more exquisite is the Smelling. All that Part which is above the Nose in the Horse or Ox, is filled with the Organ of Smelling. Those quick-scented Dogs are the best which have

the longest Noses ; for the whole Snout is filled according to the Observation of *Du Verney* with the *Ossa Spongiosa*. But in this respect the Elephant is more sagacious than the quick-scented Dog. For to this vast Quadruped Nature has given Joints that are not easily flexible, and has connected the Head by a short Neck to the Body ; but that the Elephant might be capable of taking its Food from the Earth, Nature has provided the same Animal with a long Arm or Snout extended from the Head pendulous, without which this vast Animal would have been starved. Thus the *Romans* destroyed the Elephants (which they called *Luæ Boves*) in their Battle with *Pyrrhus*, by cutting off their Snouts ; and the same Method is used at this Day in the *Indies*. But the Eyes of an Elephant are so disposed on the Sides of the Head, that they cannot be easily directed towards the Earth, so as to look conveniently round for Food ; and therefore this Snout is filled with olfactory Nerves, insomuch that the whole Proboscis, according to the Observation of *Du Verney*, is a sort of Production of the olfactory Nerves. By this means the crafty Animal is enabled to pick out a single Piece of Money mixed among a thousand others, only by the Effluvia left upon it by the Hand of its Master, as I have seen myself. Even in the Fish-kind of Animals, *Steno* has demonstrated large olfactory Nerves, like two Hands, extended to the Nose like the optic Nerves, that they might be able to discover their Prey at a great Distance.

⁸ These Birds excel other Animals both in their Sight and Smell. The Falcon, Eagle and Vulture ascend and fly through the higher Regions of the Air, that they may the better collect the Scent of the Birds, or other Animals, which lie at a considerable Distance below.

⁹ The Particles which excite Smelling are incredibly minute: A single Drop of the true Oil of Damask Roses will render a whole Pound of common Oil extremely fragrant; and yet that Pound of Oil, whose odorous Part was but a single Grain, will continue to exhale its fragrant Smell to a large Distance for many Years. Mr. *Boyle* had a Pair of Gloves in which the Smell of the Ambergrease continued for above twenty Years, and yet smelt very strong whenever he opened them. I formed a Pastil of Musk, Ambergrease and Civet mixed in a certain Proportion, and placing it in a wooden Chest not accurately closed, it has continued there for above thirty Years, still retaining its Fragrancy in a great measure: yet it does not smell at all times equally strong; for when the Air is moist or suddenly changed, it smells more intensely, whereas at other times it is very weak. The whole Affair seems to follow from the minuteness of the odoriferous Particles which no one could ever discover even by the Microscope, either in the Flower itself, or flying off from it in the Air; no one could ever perceive them either by the Taste or Touch: but at the same time in these wonderful minute Particles, there is Force enough to briskly affect the Nose. Thus we may account for the perpetual Exhalation of Effluvia from odorous Bodies without losing any of their Weight, or at least without their suffering any sensible Diminution. But it may be asked, whether or no the Air does not communicate something to the fragrant Bodies, which repairs the Weight which they lose? Thus it seems to be.

¹⁰ The foetid Smell which is sometimes imprudently drawn in from a putrefying Carcass, oftentimes leaves a troublesome Impression for a whole Day together, the Particles being confined as it

were in the viscid Mucus of the Nose. The Truth of this may be easily proved by any one who smells at the Vapours of a rotten Egg in the Morning.

¹¹ In sneezing there is first perceived a kind of Titillation under the Os Ethmoides, and then the Person waits attentively for the Effort which is to follow, which begins first with a kind of Titillation about the Diaphragm and Scrobiculum Cordis, which is always followed with a convulsive Motion or Contraction of the Muscles belonging to the Thorax and Abdomen. Medicines seem to excite Sneezing, when they are strong enough to velicate not only the olfactory or first Pair of Nerves, but also the fifth Pair; which last being very irritable, a convulsive Motion easily follows. The Nose therefore and common Sensory of the Nerves seem to be very irritable, and the most easily moved of any of the moving Nerves, namely, those Nerves are here intended which we call the first and the fifth Pair. For a Nerve laid naked in any other Part of the Body by a Wound, does not excite Pain when touched with a Feather; whereas if the same Feather irritates the Nose, it produces convulsive Motions and wonderful Gestures of Body. But though the strongest scented Bodies excite sneezing, yet the reverse of that Axiom does not follow, namely, Sternutatories do not excite Smells; for Hellebore and Antimony excite violent sneezing, and yet they do not afford any Smell.

¹² Namely, it serves to defend the Nerves and Membranes from being dried up by the Air, preserving them at the same time in a proper Condition for smelling.

¹³ The Smelling is dull of a Morning, because the Mucus which has been collected and inspissated during

during the Night-time covers over the olfactory Nerves, so that they cannot be affected by the odorous Body.

¹⁴ But the Sense of Smelling is sharper after sneezing, because the Air expelled from the Lungs with a considerable Force, abrades and carries off a great Part of the Mucus which covered the olfactory Nerves, and rendered them less sensible. But by the same sneezing also the Brain itself is shook, and the quiescent Spirits are excited into Motion. We read of a certain Philosopher, who when he was about to write any thing upon a difficult Subject, purged his Body first with a Sternutatory, or with white Hellebore.

¹⁵ The Ancients were of this Opinion. *Galen* and his Followers teach, that the Brain deposits its Mucus through the *Os Cribriforme* into the Nose: and from hence arose a Phrase of the Poets concerning stupid Men having Mucus within their Skull instead of Brains; but cautious and cunning Men were said by them to be of a quick-scented or clean Nose (*emunctæ naris.*) But the Falsity of this has been proved by *Schneiderus* in his voluminous and extensive Work *De Catarrhis*; which Book would be certainly for ever in use, if the true and serviceable Observations were collected and contracted into one Volume apart from the useless Quotations of Authors, and empty Appearances of Learning. But the Opinion of the Ancients may however be excused, inasmuch as the Mucus of the Nose is separated from the Blood of the external carotid Artery, which may possibly, by the Laws of Hydraulics, free the Blood of the internal Carotid sent to the Brain from its more viscid Parts, as we observed before at §. 231.

¹⁶ This Communication may be explained by the Tables of *Lower* and *Willis*: for it there ap-

pears that the Branches of the fifth Pair of Nerves are distributed to the four Muscles of the Eye, to the Organs of Hearing, and to the Nose, and that they communicate by a Ganglion with the eighth Pair; but the eighth Pair communicates with the intercostal and abdominal Nerves: and therefore all those Parts will be affected at the same time in sneezing; for among the other Nerves, when one is put in motion, all the rest are agitated; as if, for Instance, you should suddenly touch the Hand of a Man full of Thought with a cold leaden Bullet, his whole Body will be suddenly shook or agitated.

¹⁷ Sneezing repeated two or three times after Sleep, renders a Person brisk, and clears the Organs of Smelling from their redundant Mucus; but if the same Action be repeated twenty times, it greatly weakens by reason of the Convulsion of the Nerves, and excites a Pain in the tendinous Circle of the Diaphragm. I saw a certain Schoolmaster, who being very fond of Roses, had one given him by a mischievous Boy, which had been sprinkled over with the Powder of white Hellebore; the Master eagerly snuffed up the poisonous Dust from the Rose, but was by that means flung into such violent Sneezings, that he would have perhaps expired convulsed in a Tetanos, if the sneezing had not been suppressed by snuffing up Milk in large Quantities.

¹⁸ It is a common thing for Men, Oxen, Horses, &c. to sneeze at the first Approach of the Light, when they awake in the Morning; for the sensible Parts of the Nose are irritated by the Mucus, which has been accumulated in the Night-time; and this Sneezing removes the Cause of itself, and at the same time restores the Organs of Smelling to the distinct Perception of Smells.



Of the SIGHT.

§. 508. **U**PON the most prominent or rising Part of the Os Frontis, is seated a thick and arched *Bush*¹ of Hairs, called the Eye-brow; and in the external Margins of the Eye-lids, called Cilia, are placed a Row of erect, *stiff*² and crooked Hairs arising from their bulbous Roots in the *Cilia*³; and both these Assemblages of Hairs *defend*⁴ the Eye, as well below and on each Side, as above, serving to keep Dust or flying Insects from falling easily in to injure the Cornea.

¹ This most exquisite Organ of Sense is seated in the highest Part of the Body, namely, in the Head, which stands upon the moveable Neck, as upon an Observatory or Turret; from whence every thing may be seen both before, behind, above, below, and on all Sides. The Eye-brows stand out in such a manner, that they cover and conceal the whole Body of the Eye from every thing that might fall upon it from above: and that they might project farther, the Os Frontis in that Part separates into two Tables, the outermost of which being removed forward to form Part of the frontal Sinus's, is the Seat of the Eye-brow.

² These Hairs differ considerably from all others in the Body, both in their Rigidity and particular Incurvation; for they are inclined parallel to the Horizon, and lie ranged over each other in several Rows.

³ The Cilia are still more wonderful, being seated in an horizontal Posture in the Margin of the Eye-lids, so as to resemble very much the Bars or Pallisadoes which are placed round a City for its Defence, which they are very much like when viewed on one Side. In the lower Eye-lid there are very few Hairs, because that way the Weight of small Bodies hinder their entering into the Eye. But when these Hairs are pulled up by the Roots for the Cure of a Trichiasis, the Person is continually obliged to wink and shut his Eye-lids, lest the Eyes themselves should be injured; and there is an incredible Uneasiness arising from the small Particles which continually irritate the Globe of the Eye. These, together with the Eye-brows, defend the Eyes from too strong a Light; and therefore old Men who have lost these Hairs, are obliged to defend their Eyes with their Hand in all strong Lights.

⁴ Lest any Sweat or Humour should distil from the smooth Forehead into the Eye, or lest any Dust or small Insects with which the Air is filled, should fall into the Eye.

§. 509. The Depressor *Muscle* of the Eye-brows arising from the Os Frontis on each Side the Nose, where it joins the anterior Process of the Os Frontis, is inserted by small Tendons under the elevated Part of the Eye-brows; and by the Action of this Muscle, the Eyes are still more defended from Dirt (§. 508.), and are also shaded when placed in too strong a Light; when this Muscle is contracted, the Eye-brow is drawn towards the upper Eye-lid, and the two Eye-lids are brought

brought nearer together by it at the same Time; but the *Musculus frontalis* raises² the Eye-brow again to its former Situation when that is necessary.

¹ That the Eyes might be the better defended, it was necessary for the Brows to be moveable. To this Office therefore serves the *Musculus frontalis*, a cutaneous thin Muscle called *Panniculus carnosus* by the Ancients, who described the same as if it was seated throughout the whole Body, being led into that Mistake from their Dissections of brute Animals. This thin Muscle is easy to be discovered in the Horse, Dog, and most other Animals, in which it serves for them to shake the Skin of the whole Body, so as to throw off Insects, Flies, and other Nuisances, which they cannot remove by Hands, of which they are destitute. But this cutaneous Muscle is by the Moderns nowhere found but in the Forehead, Face, Neck, Hands and Scrotum, which Parts of the human Body are most exposed to external Injuries. The Fibres of this Muscle in the Forehead are spread under the cellular Membrane, where they are by *Du Verney* justly divided into the *Depressor Superciliorum* and *Corrugator Frontis*; and before him, *Eustachius* had depicted the same as a threefold Muscle. The latter draws the Eye-brows nearer together; and at the same Time depresses them towards the Nose. The Use of this Muscle is therefore threefold: 1. To draw the Eye-brows together, and depress them; by which means the Hairs of the Eye-brows are brought nearer to the Eye-lids, to defend the Eye from Dust, or other Particles which might slip into it; and therefore we draw down our Eye-brows when we walk through a dusty Place. 2. They serve as a Shade

to moderate the too strong Rays of the Sun when we walk in the Day-time ; as we see naturally follow, when we front the Noon-sun, or any other strong Light. 3. When we endeavour to discern very distinct Objects, we draw the Eye-lids closer together and form a Shadow, under which the Pupil dilates itself, so as to receive a greater Number of the diverging Rays coming from the distant Object. And this is the Reason why old People see more distinctly through a Tube which is black on the Inside.

² It elevates the Eye-brow whenever the square Muscles of the Occiput retains the frontal Muscle to which it is continued ; for then the Direction is changed, and the Eye-brows are drawn backward and upward over the Forehead. And this happens whenever we suddenly look upward and rejoice. Hence a smooth Forehead signifies a quiet Mind. But the Fibres of this Muscle do not run directly upward, but obliquely, as *Eustachius* has justly exhibited in his Tables.

§. 510. The two *Eye-lids* ¹ are *membranous* ², thin, folding together, replenished with *Vessels* ³, and furnished with nervous *Papillæ* ⁴ on their Inside which is continually *moistened* ⁵ ; being defended with a broad *arched* ⁶ Cartilage in their Margins where they meet together ; and these by their opening, shutting or winking by an alternate Motion, do likewise *defend* ⁷ and cleanse the Eyes. For the *elevator* ⁸ Muscle of the upper Eye-lid, arising narrow and fleshy from the Bottom of the Edge of the bony Orbit, passes over the elevator Muscle of the Eye, and expanding itself into thin tendi-

nous

nous Fibres, is wholly inserted into the upper Part of the Tarsus, or cartilaginous Edge of the Eye-lid; and it serves by its Motion to raise or draw up the superior Eye-lid without Wrinkles. But the Sphincter or *round Muscle* ⁹ of the Eye-lids arising from the larger Bone of the Nose, and spreading its orbicular Fibres over each Eye-lid, it serves by contracting itself like a Sphincter to apply them by a moderate Motion towards each other, and by a stronger Contraction to press them against the Globe of the Eye, as well as to express the Tears, and apply them to the external Surface of the Eye, so as to wash away the Sordes. But the lower Eye-lid is opened by a spontaneous Contraction of *muscular Fibres* ¹⁰ distributed into the Cheek.

¹ They are a Sort of Curtains, freely moveable over the Eyes, which they cover in Sleep, and which serve to cleanse the Eyes and keep them moveable. For there are two Lids belonging to each Eye, divided from each other by an horizontal Slit.

² The Eye-lids are composed of the following Membranes. 1. The Cuticle which is extremely thin, as evidently appears when it scales off towards the Declination or End of an Erysipelas. 2. The true Skin itself, which is very thin. 3. The cellular Membrane as thin as the Web of a Silk-worm, though it wonderfully swells in Diseases, even from a slight Cause, as in the Small-Pox, or an oedematous Erysipelas, where it is sometimes an Inch thick. Also in the Beginning of a Dropsy there appears a distended Tumor
round

round the Eye, which is commonly with good Reason reckoned among the Signs of a Deficiency in the vital Powers. But this Part of the cellular Membrane is never distended with Fat, even in the most corpulent Person. 4. The muscular Expansion of the elevator Muscle, which is lined with a vascular Stratum. 5. The Stratum of Papillæ. 6. An exceeding thin Membrane like a Spider's Web, destitute of any Skin, Cuticle or Glands, and lying next to the Eye itself, being so subtle and pellucid that upon turning back the Eye-lid, one would imagine that they saw the naked Vessels without any Covering; when at the same Time they are invested with this fine Membrane. Thus are the Eye-lids composed of so many thin Membranes, so as to be elevated and depressed without any apparent Wrinkles.

³ The numerous Vessels of the Eye-lids are demonstrated by filling them with ceraceous Injection. And even upon turning back the Eye-lid in a living Person, the whole appears a dreadful Spectacle distended with red Blood, such as we never observe in the Skin of the Face; nor are the Arteries in any Part of the Body exposed so naked as in this. By these numerous small Arteries therefore the Eyes are maintained warm, while the other Parts of the Face are cold: for these numerous small Vessels of the Eye-lids continually administer Warmth to the Eye and its Humours. These same Vessels also discharge a thin insipid Water, with which the Eye is moistened.

⁴ The convex Surface of the Eye lies under the concave Part of the Eye-lids, which being destitute of the Skin and Cuticle, are only covered with so thin a Membrane, that the least Violence destroys it. But to prevent a Destruction of this Membrane, Nature has placed a faithful Guard to
give

give Notice; namely, Pain, which is seated in the numerous and naked Papillæ. These Papillæ are demonstrable by cutting off a Part of the Eye-lid and macerating in Water; by which means the whole internal Surface appears unequal or villous, like fine Velvet: but so sensible are these Papillæ, that the smallest Particle of Sand slipping betwixt them and the Eye, excites a most intense Pain, which never ceases till there is a Quantity of Tears sent to the Eye, sufficient to wash out the offending Matter; but if the offending Body is not thus naturally washed out, warm Water is to be injected by a fine Syringe betwixt the Eye and its Lids; by which the offending Matter may be discharged, and the injured Eye-lids relieved. If quick Lime falls into the Eye it produces the most extreme Torture, and sometimes even Blindness itself; and in this Case there is no other Remedy than to take a Mouthful of Water made warm, and blow it betwixt the Eye-lids turned back. But when an Ophthalmia or other external Disorder has destroyed the thin Skin of the Eye-lid, an intense Pain continues Day and Night, which cannot be removed but by injecting Milk or the Blood of young Pigeons.

⁵ This moistening Liquor arises from the hygrophthalmic Ducts of *Meibomius*, and from the Vapour of the exhaling Arteries conjoined together; the former is properly the Tears, but the latter exhales in the Form of a Vapour, betwixt the Convexity of the Eye and the Concavity of its Lids, that the Membranes touching each other might not be very dry, which would certainly cause them to grow together, so as to produce a Symblepharosis, but which is called by *Celsus* and the Ancients Ancyloblepharon. This is a lamentable Disorder, but curable by continually injecting some emollient

emollient and diluting Liquor Day and Night. Hence it frequently happens that the Eye and its Lids grow together in the Small-Pox and Measles ; and in this Case neither the Eye-lid alone, nor the Eye itself can be elevated. Those who are afflicted with this Disorder cannot turn their Eyes upward, unless assisted by the Hand of the Surgeon ; but the less knowing Physicians often falsely ascribe this Disorder to a Palsy.

⁶ A very exact Segment of a Circle, whose Circumference includes the Edge of the Eye-lids. These Tarfi being cartilaginous, do by their Firmness keep the Eyes paralled and free from Wrinkles in all Positions, so that they never collapse either when they are elevated or depressed. For unless the whole Eye-lid was kept equally stretched, it would be continually wrinkled at the time of its elevation, and the Wrinkles would rise up towards the larger Angle of the Eye, not without some Uneasiness to the adjacent Parts.

⁷ The Eye-lids serve, 1. To keep the Eyes moist externally, that they may never become dry, wrinkled, or opake. 2. To cover the Eyes in the Night-time, which would otherwise be soon spread over with a Crust, so as to be stopped up by the Dust which continually floats in the Air. 3. To cleanse the Eye every Moment, almost in the same Manner as Flies, who, that they may ascend a very smooth perpendicular Plane, as Glass, are furnished with little Hooks in their Feet, which they continually rub and cleanse with their Fore-feet, lest they should become useless by their being covered over with any viscid Matter. Thus our Eye-lids are continually moving Day and Night, to wipe off and remove the Dust, which flying in the Air might concrete with the Humours of the Eye, and incrust it over.

This

⁸ This was first depicted by *Eustachius*, and afterwards described by *Fallopianus*, though the Use of it was not well understood by *Lancisi*. It arises tendinous from the bony Arch of the Orbit, and ascends over the Rectus Attolens Muscle of the Eye, and betwixt the cellular and papillary Membranes of the Eye-lid; its fleshy Fibres are spread like rays, and continued even to the cartilaginous Edge or Tarsus, into which they are inserted tendinous. When these muscular Fibres are contracted, they raise or elevate the Eye-lid equally on all Sides; but the Action of this Muscle is assisted by the adjacent Fat lodged in the cellular Membrane. This Muscle is very distinct from the right elevating Muscle of the Eye; and from hence Anatomists have taken occasion to reckon seven Muscles for the Motion of the Eye. When this Muscle is convulsed, as it sometimes happens in Epilepsies, the Eye stares and remains continually open. Surgeons ought to be careful that they do not cut this Muscle in the Middle; for it would be followed with an incurable Palsy of the Eye-lid, which falling down would in a Manner bury the Eye itself. To cure this Disorder, *Bartischius*, a German, in his very scarce Treatise entitled *Ophthalmodulia*, orders the Eye-lid to be intercepted betwixt the two wooden Pliers, cut off, and afterwards consolidated; thus the Eye-lids are prevented from collapsing or descending too low upon the Eye in a disagreeable Manner. There has been also a Controversy about the same Operation, betwixt *Ruyfch* and *Raw*.

⁹ This orbicular Muscle antagonizes the former, being in some Measure assisted in its Action by the Weight of the Eye-lid. It strongly draws the Eye-lids into mutual Contact, depresses the upper Eye-lid

Eye-lid and elevates the lower, shutting up the Eye, or permitting it to see only through a small Fissure betwixt the Eye-lids, at which time the elevator Muscle is at rest. This orbicular Muscle being much stronger than its Antagonist, shuts the Eye with an almost irresistible Force, at the Approach of Sleep, as we see in Children, who at an Entertainment are neither willing to leave the Company, nor yet are they able to keep their Eyes open. And even adult Persons being awaked out of a Doze, are scarce able to overcome the Power of the orbicular Muscle, except by rubbing their Eye-lids. This orbicular Muscle serves also to cleanse the Eye; for by contracting the Eye-lids, it presses out the Tears, and moving them over the Surface of the Eye, it at length expresses them together with the Sordes dissolved or mixed with the Tears. But their fixed Point or Origin being towards the Nose, they make the Globe of the Eye turn that way; and as the same Muscle arises and is distributed before the Eye, it presses the Globe backward into the Orbit. But the Bulb of that Eye being thus repelled compresses the lacrymal Gland, so as to force out the Tears, which are there separated. Obstinate Children when they endeavour to move their affectionate Mothers to grant what is denied, squeeze the Balls of the Eyes with their Fist, and by that Means force out the Tears from them. This Muscle being violently contracted in a strong Light, or in a sorrowful Disposition of Mind, occasions the Tears to flow so plentifully that they run down the Cheeks. Whores craftily force out Tears by the Action of this Muscle, to move and reduce the Minds of young Men to a Compliance. Lastly, this Muscle is seated in the cellular Membrane; and hence it is that it does not corrugate the Eye-lid.

¹⁰ The lower Eye-lid is depressed, 1. By its own Weight. 2. By the Muscles of the Cheek drawn downwards, and detracting the very moveable Eye-lid at the same time. When the Fat of the Cheeks has been consumed by extreme Leanness, and the Muscles of those Parts are more contracted, these Fibres are not raised above the lower Eye-lid, nor is the Eye quite shut, but some Part of its White appears uncovered. Hence *Hippocrates* ranks the Appearance of the White of the Eyes in Sleep, among the Signs of Death; except the Disorder should arise from a meer shrinking or Smallness of the Eye-lids. *Du Verney* wrote to me formerly, that he had found an orbicular constrictor Muscle shutting the Eye-lids, which had two Bellies with an intermediate Tendon. But afterwards in his Letters since wrote, he takes no Notice of the Discovery; whence it would seem that he had met with something accidentally, which does not frequently occur.

§. 511. But lest the Eye-lids should be excoriated by continually striking against each other in *winking*¹; therefore there is a Row of small *Glands*² like little Grains of Sand, seated in the cartilaginous Edge of each Eye-lid, and which separate a yellow humour, as if it were compounded of Oil and Wax mixed together, discharged by open Ducts, perforating the cartilaginous Tarsi of the Eye-lids themselves: the Mouths of these excretory Ducts are the Extremities of small Vessels, which are here disposed in a serpentine Course, and arise immediately from the small Arteries, which are here distributed, without any intermediate glandular Fabrick.

¹ The cartilaginous Tarfi continually strike and rub against each other in winking with the Eyelids ; infomuch that we ourselves, or our Friends standing by, may hear a Sound as if it proceeded from the Collision of elastic Bodies, provided there is a profound Silence. But such frequent Percussions repeated perhaps more than a thousand times in a Day, and that with some Violence, must necessarily by the Attrition wear away the Parts in Contact, infomuch that sometimes we have seen little bleeding Fringes from the Attrition of the Perichondrium or thin Membrane which invest the Cartilages of the Tarfi ; but to prevent this Accident they are furnish'd with these Glands separating this unctuous Humour.

² These small Glands are conspicuous enough upon turning out the Eyelid, appearing like small Grains, by pressing which a Sort of Liniment is discharged, which mixing with the glandular and arterial Humour, forms Part of the Tears. These serpentine Inflexions of the Ducts have been demonstrated by *Ruyfch*, and his red Wax being happily injected, has return'd white thro' these Ducts, whence he rather esteems them Continuations of the Arteries than real Glands ; they seem in short to be no more than Cryptæ, into each of which many small Arteries meet together, and discharge an aqueous Humour, which by standing grows viscid and thick, and is expressed at the time of winking, spreading itself over the cartilaginous Margins of the Eyelids, which it lubricates, and being dry'd up appears like a white insipid scaly Matter. When this Liniment is absent, the cartilaginous Margins of the Eyelids rubbing together are inflamed, and glue together in the Night-time, infomuch that they can be scarce open'd in the Morning without the Assistance of warm Water.

ter. In these glandular Cryptæ, like small Grains are formed those small Tumors which are called by the Name of *Chalaza* or *Hordeolum* of the Eye-lids, which may at length turn into an *Atheroma*; these are found as well in the Margin of the upper as the lower Eye-lid.

§. 512. The large conglomerate Gland, termed *Glandula innominata*, being broad, flat, and unequal, is *situated*¹ within the Orbit, towards the external Angle of the Eye, near the rough Fissure or Chink, being involved in Fat, and furnished with Arteries, Veins, Nerves, and lymphatic Vessels, with hygrophthalmic *Ducts*²; discharging the Moisture which *waters*³ the Eye; this Gland separates a brackish, watery, pellucid Humour from the arterial Blood, which is mild to the Taste, and continually discharged in a small Quantity, but *abounds*⁴ more plentifully when the Eye is rubbed, or when this Gland is compressed together with the Eye by the Action of the orbicular Muscle of the Eyelids; so that by the Flux of this Humour from above, betwixt the Globe of the Eye and the internal Surface of the upper Eyelid, the Eye itself is continually moistened, lubricated, washed clean, and the Eyelids themselves prevented from growing together. When this Humour is redundant, or separated in too large a Quantity to be absorbed by the lachrymal Points, it is called Tears. The same Humour may perhaps be likewise separated for the same Uses by small Glands seated in the upper Eyelid.

¹ This Gland is securely situated in a sort of Excavation within the Orbit, which seems as if it was impressed by the Thumb, the Length of it being nearly equal to one third Part of the Orbit. This Gland is the Seat of great Disorders, for it sometimes degenerates into a Scirrhus and a Cancer, thrusting the Eye itself out upon the Cheek; nor is a Tumor of this Gland to be removed without the greatest Difficulty, if at all; if therefore an Inflammation is perceived in this Part, all proper Assistances are to be timely used, that the Patient may not for ever after be troubled with an *Oculus Elephantinus*, or protuberant Eye.

² Which Ducts always run in great Numbers thro' the internal Membrane of the concave Surface of the Eyelid, opening here and there obliquely, and watering the external Convexity of the Eye.

³ That the external convex Surface of the Globe of the Eye may continue smooth, and wash'd clean from all the small Particles which may fall into it from the Air, which abounds with Dust, Insects, and other Nuisances. There was the greatest Necessity for the Eye to be continually moistened with this Humour; for the Laws of Dioptrics require the Eye to be always of the same Figure, for which reason it is continually distended with extravasated Humours internally. But together with this constancy of Figure, the Eye was required to be flexible (*per* §. 530.) and therefore that Flexibility made it necessary for the Eye to be continually moistened.

⁴ In sorrowful Affections of the Mind the orbicular Muscle of the Eyelids strongly compresses the lachrymal Glands, as also it does in various Pains and Inflammations of the Eye. When a little Particle of Sand, or a single Drop of Vinegar has

has fallen into the Eye, the orbicular Muscle contracts and presses the lachrymal Gland, and continues washing the Eye until the offending Body is discharged. Nor can the Influence of the Will suppress this Flux of Tears. Lastly, this lachrymal Humour runs down over the Cheeks, whenever the pituitary Membrane is tumefied, so as to compress the nasal Canal, that its Capacity is not sufficient to receive or transmit all the Humour which when redundant from any Cause, so as to run down the Cheeks, is called Tears.

§. 513. But both these Humours (512) together with the absterged Sordes, are directed by the determinate *Figure*¹ and Concourse of the cartilaginous Margins of the Eyelids towards that *Space*², which is left free in the larger Angle of the Eye for the Reception of them, and for the spongy Caruncle which is there seated; and here the *grosser*³ Parts being stopped, and gather'd together upon the rough Surface of the fore-mentioned Caruncle, are at length dried into gummy Scales; but the more fluid Parts are wonderfully pressed by a determinate Motion into the dilated Points or lachrymal *Foramina*⁴, seated in the extreme Angle of each Eyelid, and usually denominated the *Puncta lachrymalia*; from whence the lachrymal Ducts arising, meet together behind the Caruncle into the lachrymal *Sack*⁵ seated in the nasal Canal, which is formed by the Concourse or Meeting of the *Os unguis* with the anterior Part of the upper Jaw-bone; from which Sack the Humour is

continually discharged by an open Duct into the Cavity of the Nose, immediately under the lower *Os spongiosum*; hence appears the reason why those that cry have a Running at the Nose, and why there is not the Appearance of any lachrymal Humour in People who are under no Uneasiness.

¹ The orbicular Muscle first compresses the Part where there is the least Resistance, namely, the external Angle of the Eye, and from thence it gradually proceeds, contracting towards the larger Angle; and thus by a mechanical Necessity the Humours of the Eye are determined from the external towards the internal Angle.

² The cartilaginous Margin of the Eyelids is broke off towards the internal Angle in such a manner, that in that Part the Eyelids do not touch each other, but leave a small intermediate Space; in that Space is seated the *Caruncula lachrymalis*, as it is commonly, but improperly called; namely, a particular kind of fleshy Substance, much resembling a Strawberry, and on all Sides beset with most minute Hairs, as they are called by *Morgagni*, from whence the Ancients falsely imagined the Tears to arise; this Substance is therefore formed by Nature to fill up the Space left betwixt the Eyelids, and to serve as a Strainer, to stop the Sordes from entering and obstructing the lachrymal Points.

³ The Fæculencies being excluded from the Orifices of the lachrymal Ducts, are stopt and retain'd by the most minute Hairs of the Caruncles; where being collected, they are at length condensed into rough Scales, which seldom appear in the Day-time, because we then frequently clear the
Eyes

Eyes by rubbing them ; but in the Night-time they are often found, even in the most healthy People, being the white Substance so frequently mentioned by *Hippocrates*. When we walk thro' the Dust there is by this means formed such a viscid and opake Crust, that it obstructs the Eye, and renders it necessary to wash it off. These Sordes are composed, 1. Of the unctuous Liniment from the sebaceous Glands (511) 2. Of the Dust and other Particles catched and received from the Air. 3. From the grosser Parts of the lachrymal Humour itself. These Fæculencies are collected in greater Quantities in the Eyes of Brutes, more especially in those which live in dusty or sandy Places, as in the Elephant and Stag, in which they degenerate into Stones, being received by the *Arabians* among the officinal Simples under the Title of *Lapides de oculis cervi*.

4 These Points or Foramina are so large that they are capable of receiving a Bristle ; thro' these all the Humour is absorbed, which is pressed from the lachrymal Glands by the winking of the Eyelids, while grosser Parts are stopt by the lachrymal Caruncle.

5 This Sack is a Cavity, formed without by Membranes, and within by Bones joined together, namely, the *Os unguis* and upper Jaw ; to which Sinus the Tears are conveyed in a direct Course thro' the lachrymal Points, or any other Humour that is injected betwixt the Eye and its Lids instead of the Tears ; and from this Sack the Humour is discharged by a continued Canal running under and parallel to the Eye above the Palate, and into the Cavity of the Nose. From this Fabric of the Parts which we have hitherto explain'd, arise four Kinds of lachrymal Fistulæ ; the first of which is when the lachrymal Points being lacera-

ted, inflamed, or excoriated, grow together; whence the Tears are not absorb'd, but stagnate in the internal Angle of the Eye, excoriate the Eyelid, and make themselves a filthy Drain, thro' which they perpetually distil over the Cheek. The second Species is when the lachrymal Canals grow together betwixt the Sack and the Points; and the third Kind is, when the lachrymal Sack itself is obstructed or concreted together after an Inflammation, or stopt up by the inspissated Matter of the Tears. The fourth and last Species is, when from any Cause the Emissary within the Nose itself is obstructed or compressed, whether by an Inflammation or Distention of its Membrane in a Cold or otherwise; which Obstruction being removed, the Tears again discharge themselves by their usual Course. All these Disorders are commonly treated, without any reason, by one and the same Method; namely, by actual or potential Cauteries; when the only true and successful Method of relieving the Patient, is by removing the Obstructions of these several Canals.

§. 514. Thus therefore the Eyes, continually expos'd to the Air, are kept *moist*¹, *clear*², *transparent*³, *slippery*, *flexible*, or *yielding*⁴, *soft*, *warm*, and *moveable*⁵; and are also by the same means readily freed from every thing which is rough or acrid that happens to fall into the Eyes, and are continued in a fit Condition to be equally expanded by the internal distending Causes.

¹ When the Force of the Vessels is so much weakened as to deny the usual Supplies of the hygrophthalmic Liquor, the Eye becomes wrinkled, and

and remains in the middle of Death a moving Spectacle; but so long as we continue in Health, Nature takes care not to let this Liquor be wanting. If a Child should be exposed to the dry Air in hot Weather, the Eye will appear to wink continually as long as it is dried by the Air; and those Winkings will be repeated whenever the Eye becomes dry again.

² The Eyes in a healthy Person look agreeably splendid; but when their shining is removed, the Eye appears frightful and stern to those who behold it.

³ When the Tears are wanting, the Transparency of the Eye is continually impaired, and it becomes opake, in the same manner as when it is dried by the Air after Death.

⁴ There was the greatest Necessity for the Coats of the Eye to be kept flexible in order to preserve the Sphericity of its Figure; for unless every Fibre of the Eye remains equally lax, it would not be expanded by the vitrious Humour internally into a perfect Sphere, but would resemble a Body having many Angles, being most prominent in those Points of the Circumference where there is the least Resistance; for *Bernoulli* has demonstrated, that a Circle will be formed when the Liquor within presses every way with an equal Force upon an equally resisting Line. Hence in old People, and in those who are near Death, the Eye becomes stiff and flat; and this is the reason why those who are long-sighted are obliged to correct the Flatness of their Eyes with a convex Glass, which collects the Rays together more than the Eye itself. But in dead People the Alteration in the Figure of the Eyes is still greater, and is vulgarly called breaking the Eyestrings.

⁵ The Eye is hardly ever at rest, but is continually moving even under the Eyelids, and when the Eyelids themselves are at rest.

§. 515. The *Fabrick* ¹ of the Eye and the Action of it thence resulting, will be best understood if we begin first with the optic Nerve, and then proceed to consider all its other Parts, and their Offices, in that Order in which they depend upon the Nerve.

¹ The Eye may be considered as an optical Tube, (as *Perrault* long ago observed) whose Object-Glass is the first Membrane termed the Cornea; the Glass which brings the Object nearer is the crystalline Lens, behind which lies the vitrious Humour; the Partition excluding the refractive Rays is the Eyes with the Pupil and Uvea, and the Choroides performs the same Office with the black Tube.

§. 516. The optic *Nerves* ¹ proceeding from the upper Part of the medullary Substance of the Brain, which lies under the Corpora Striata, descend from thence downward, and most strictly *unite* ² together under the Infundibulum; then separating again from each other, they proceed towards each Side from whence they came with their Fibres, and penetrate into the round Foramina in the Bottom of the Bony Orbits of the Eyes. Through all this Course the optic Nerves continue soft and *porous* ³, and are covered only with the thin but tough Pia Mater of the Brain;

Brain ; which furnisheth them with a great many Branches of *Arteries* ⁴, as they pass along securely under the suspended Brain. But in their Passage through those round Foramina of the Orbit, they are also covered with the Dura Mater, which like a *Sheath* ⁵ strongly adheres to the former Membrane ; and thus they pass thro' the Foramina into the Cavities of the bony Orbits of the Eyes, where the Dura Mater itself is also found spread with many small Arteries.

¹ In an Embryo the Eye is much greater in proportion to the other Parts of the Body, than in an Adult ; and even as the nervous System is usually very large in the incipient Animal, yet the Eyes are in many Kinds of Embryo's almost equal to the Brain itself. It appears from the Observations of *Malpighi*, that the Eyes then bear so large a Proportion, as might induce one to believe that the whole animal Machine was only formed for the sake of the Eyes. The Head is equal to a third Part of the whole Animal, but the Eyes make up half of the Head ; and even in Fish that are adult, the Brain itself is no longer than the Eyes ; and in those Fish the Eyes are really a Production of the Brain. Thus the Bulk of the optic Nerves is very considerable, and pass through Foramina proper to themselves, which are not inferior in Size to those of the largest Nerves.

² This Conjunction of the optic Nerves must be evidently of the greatest Use, since they are constantly observed in almost every kind of Animal. I am almost apt to suspect, that half of the Medulla arising from the right Corpus Striatum passes to the right Eye, and half to the left ; and

on the other hand, that from the left Corpus Striatum half of the Medulla passes to the right Eye, and half to the left: and hence we may possibly derive the Reason why we see but one and the same Object when we look with two Eyes. In Fish this Conjunction of the optic Nerves is not to be found. In the Chameleon the Eyes are seated laterally in the Ossa Temporalia, whence this Animal is obliged to turn his Head on one Side to see.

³ The optic Nerves are truly a Production of the Medulla of the Brain, properly so called; being quite porous throughout, which we do not observe in any other Nerve. In the middle of the Nerve there is also a Foramen which was not unknown to *Galen*, and is plainly delineated by *Eustachius*, who seems to be much rejoiced that he had an Opportunity of supporting the Opinion of *Galen*, in opposition to the other Anatomists: and which Foramen though denied by many Writers, is yet constantly in the Center of the optic Nerve, and transmits an Artery which ought never to be forgot, as it is distributed throughout the middle of the Retina. This Artery has been exhibited by *Ruyfch*, and seems to have been designed by Nature to warm the Medulla of the optic Nerve with the vital Blood. From this Fabric we are capable of accounting for many Appearances and Disorders of the Eye. An ancient Writer, *Aetius*, observes, that in the most inflammatory Diseases of the Head, and after a Phrensy follows an Amaurosis which the *Arabians* call a Gutta Serena, but which is a perfect Blindness, in which there is no apparent Change to be seen in the Eye. But this Disorder, says *Aetius*, gives way to no Medicine; but when the Disorder is removed by a salutary Crisis, it vanishes of its own accord.

accord. For in this Disorder the soft Medulla of the optic Nerve is compressed and obstructed by the Distension of the circumjacent Arteries.

* There are four small Arteries which pass along to the optic Nerves at its four Sides : but besides this there are Nerves sent to the exterior Parts of the Eye, from the third, fifth and sixth Pair, for Motion and Sensation.

5 Where the optic Nerves pass out of the Cranium, they receive a membranous Covering, which does not seem to be a Production of either of the Meninges, nor of the Tunica Arachnoides. The Membrane is indeed thick and strong, receiving small Branches of the fifth Pair of Nerves as well as small Arteries, being destined for other Uses different from that of Vision.

§. 517. These bony *Orbits* ¹ of the Eyes are lined internally with the *Periosteum* ², which arises from the Dura Mater itself, reflected back at the same Place, where it invests the optic Nerve ; and being filled with a large Quantity of *Fat* ³, the Globe of the Eye is received and secured in the same, as upon a Cushion : and thus the Eye is defended, lubricated, and rendered easily moveable.

¹ These Orbits are formed by Nature of several Parts of Bones ; nor could it otherwise be capable of growing or increasing, since a perfect Sphere violently opposes Expansion ; nor would the Muscles of the Eye nor lachrymal Glands permit these Cavities to be of a spherical Figure. For the Eye continually grows, though it does not increase in the same Proportion with the other Parts of the Body.

² All the Periostea or Membranes which invest the Bones of the Body cohere with the Dura Mater: for this gives a Case to the Medulla Spinalis; (§. 304. N^o 4.) and from thence arise the external Periosteum of the Spina Dorfi, together with all the Vaginæ or Cases of the Nerves.

³ It is this Fat which in the Eyes of Brutes is so relishing and agreeable to the Taste. It serves to keep the six Muscles of the Eye perpetually soft and moveable. We should not be capable of seeing unless the Eye was perfectly spherical; for if you press the Eye with the Finger, so as to alter its spherical Figure, that Eye will be blind for a little Time. This Figure of the Eye arises in a great Measure from the expanding Force of the Humours within; but this would not produce a Sphere unless the Membranes gave way equally on all Sides externally, which is most happily provided for by encompassing them in this Manner with soft Fat. When this Fat is consumed the Eyes appear hollow, sorrowful, and like those of a dying Person. For the Bulb of the Eye is much less than the Orbit. In this Fat is the Seat of various Diseases, and sometimes Suppurations, which thrust out sometimes the whole Tunica Adnata from the Orbit, without injuring Vision. In this Case, a skilful Surgeon perforates the Tunica Adnata by Puncture, with the Scalpell; by which the Matter being discharged the Eye recovers its former healthy State.

§. 518. In the next Place the *Vagina* ¹ or Covering derived from the Dura Mater to the optic Nerve, enters the Orbit above the fore-mentioned Fat, and soon after this external Covering of the optic Nerve expands
itself

itself into a membranous and almost perfect Globe, hard and tough, like Leather, wrapp'd round the whole Eye, and growing gradually *thinner*², is at last more thin, prominent and pellucid in the fore-part, where it is called the *Sclerotica*, so far as it is white and opake; but where it is thinner and pellucid it is term'd *Cornea*³; it serves principally to keep up the Figure of the Eye, sustain its Vessels, and support its Muscles with their Tendons; for thro' this Membrane enter the Arteries and *Nerves*⁴ of the Eye.

¹ This membranous Vagina or Covering being extended to the Margin of the round Foramen in the Bottom of the Orbit, receives the optic Nerve in its Middle; and after passing a small Distance together, it is then expanded into the *Sclerotica*, so called from its Hardness. But I must confess myself to have been formerly of the Opinion of those who suppose the *Dura Mater* to form the Periosteum of the Orbit, and make the *Sclerotica* a new and distinct Membrane.

² It is thickest at the Bottom of the Orbit or Globe, and is gradually extenuated forwards; thus the *Sclerotica* of the Eye in a Whale is an Inch thick at the Bottom of the Globe, whereas in the fore-part it is hardly four Times as thick as Paper; it renders the Figure of the Eye permanent, that it may not be liable to Alteration from the Pressure of the Muscles.

³ In the anterior Part of the Eye we observe three distinct Colours; the whole Circumference appears white, namely, so far as the *Tunica adnata* extends; but in the Middle of the *Adnata* appears a grey, light, blue, or Ash-colour'd Circle, sometimes

times blueish, or inclin'd to red, to which is given the Name of *Iris*; in the Center whereof appears a round black Opening, called the *Pupil*. Before the *Iris*, is expanded the *Cornea*; namely, the *Sclerotica* itself continued, only changing its Name where it changes its Colour and becomes transparent. The *Cornea* consists of pellucid Lamellæ, almost like those of Horn. When the Eye is thrust forward so as to distend the *Cornea*, and you then suddenly wound it with a Knife, it discharges a great Number of aqueous Drops, which is a Sign that it contains small lymphatic Vessels. In Inflammations of the Eyes the whole *Cornea* sometimes looks red, when the red Blood has penetrated into these pellucid Vessels.

4 The ophthalmic Nerves of *Raw*, arising from the third and fifth Pair, which penetrate into the Eye, and perforate the *Sclerotica* in sixteen different Parts; from these Nerves arise the external radiated muscular Fibres of the Pupil, which dilate it, and the internal orbicular Muscle, which contracts the Pupil, together with the small transverse Muscles withinside the Iris, where it lies incumbent upon the crystalline Lens; lastly, those Muscles which are called the ciliary Processes, which are implanted into the Margin of the crystalline Lens above the lateral Ring; all these small Muscles are entirely composed of medullary Fibres, into which the small ciliary Nerves are continued and degenerate.

§. 519. But the Membrane which involv'd the optic Nerve being continued from the *Pia mater* ', and having enter'd the Orbit or Globe of the Eye together with the same Nerve, lines the hollow Surface of the Sclerotica,

rotica, and divides itself into two Lamellæ or Plates, which are divisible, and spread with an infinite Number of distinct Arteries of different Courses, as appears from the Injections of *Ruysch*; and thus this Membrane is continued forward to where the Sclerotica forms the Cornea, and there receding *inwards* ² from the Sclerotica, it first gives a very thin Membrane, which is spread upon the *vitreous* ³ Humour; and in the second place it forms the *Tunica Uvea* ⁴, in the middle of which is a Perforation called the *Pupilla* ⁵. That Lamella which lies contiguous to and incumbent on the Sclerotica, is termed the *Choroides*; and the other Lamella which lies within the former, is term'd *Tunica Ruyschiana* ⁶.

¹ Which being derived from the *Pia Mater* and *Tunica arachnoides* of the Brain, and changing its Nature, so as to become more tough, and being furnish'd with Arteries, leaves the optic Nerve, and lines or covers the whole Globe of the Eye, except in the round Limb or Circle where the *Sclerotica* terminates and forms the *Cornea*, and where the Eye, which before appeared white, begins to be painted of a different Colour; for there it deserts the *Cornea*, recedes inward, and forms a pendulous Membrane under or at some Distance from the *Cornea*, being perforated in the middle by the Pupil; nor could this Membrane possibly invest the *Cornea* like the rest of the Sclerotica, without obstructing its Transparency, which would have frustrated the whole Design of the Organ. But the first who demonstrated that the thin Membrane of the Brain is composed of two different

Lamellæ, the upper of which is the *Arachnoides*, and the lower the *Pia Mater*, a meer Network of Vessels, was one *Matthew Slade*, a *Dutch* Physician, well skill'd in Antiquities and in *Greek* Poetry, being one of the Anatomical Society at *Amsterdam*, with *Blase*, *Quina*, and others. From the former of these two Lamellæ of the *Pia Mater*, namely, from the *Arachnoides*, is deriv'd the *Tunica Choroides* of the Eye; and from the vascular Lamella, or the *Pia Mater*, properly so called, seems to be derived the *Tunica Ruyschiana*, which lines the *Choroides*.

² Thus by receding from the middle of the *Cornea*, it leaves an intermediate Space, in which it fluctuates in the midst of the aqueous Humour.

³ A very fine Tunic which forms the Cells wherein the aqueous Humour of the Eye is contained, (See §. 528.) and confined in the Cells like a soft or consistent Body.

⁴ Thus it is called with respect to its internal Surface, but externally it is term'd the *Iris*; the Colour of which is various in different People, as grey, black, blue, &c. the latter is the external Surface of the *Choroides*, and the former its internal Surface. (See §. 520.)

⁵ Nor yet do either the *Choroides* or *Tunica Ruyschiana* form a compleat Circle or Sphere, but are in a manner perforated so as to leave a Foramen, which is denominated the *Pupil*.

⁶ So called, as being demonstrated by *Ruysch* to be separable from the *Choroides*, and spread with a different Series of Vessels; for the Vessels of the *Choroides* spread on all Sides like Rays from a Center.

§. 520. But while the Margin of the Choroides recedes and forms the Uvea, it receives Nerves¹ at the same time from those which perforate the Sclerotica together with the Choroides, and being there communicated to the same, are divided into many small Branches; from these Nerves and Membranes are form'd the exterior muscular Fibres of the Uvea, tending from their Origin towards a Center, and terminating in a circular Ring composed of circular and muscular Fibres, which determine the Figure and Capacity of the Pupil; and this circular Rim or Border which terminates the Pupil, being reflected back towards the Cavity of the Eye, becomes three times broader than it appears outward, and receives the internal strait Fibres of the Uvea, and binds them together in the same manner; from hence it is evident that the orbicular Fibres contract, and that the longitudinal ones dilate the Opening of the Pupil; but the thin pellucid Membranes which connect the Fibres together, are covered over with a very black-colour'd Pigment on that Side which is opposed to the back Part of the Eye.

¹ Betwixt the Choroides and Tunica *Ruyfchiana* run the Nerves, with the arterial, venal, and lymphatic Vessels, together with aqueous Ducts; these Nerves run from the whole Circumference of the Choroides towards the Pupil, and form muscular Fibres, which are inserted into the Ring of the Pupil, like Rays tending to a Center from a Circle, serving to open the Pupil, by drawing its

Rim towards the more firm or fixed Part of the Choroides ; these therefore admit Light more copiously, and increase the black Part of the Eye, while they diminish the coloured Part of the Iris. This may be easily demonstrated by Experiment in a Friend ; for if you look at his Eyes exposed to a strong Light, the coloured Part of the Eye which makes the Iris will appear as large as possible ; and on the contrary, if you inspect his Eyes in a dark Place, the Pupil will appear extremely large, and the coloured Part of the Eye but very small. The same Dilatation of the Pupil is also perceived in Twilight, or when the Light is so weak that it does not sufficiently illuminate the Object. But these Fibres terminate in a Ring or Circle, which immediately encompasses the Pupil or Opening of the Eye, to which it is a true Sphincter, appearing much more distinct in the Eye of a Whale than in a human Eye. This Ring, which immediately encompasses the Pupil, being reflected inward, appears three times larger on the Side of the Uvea ; for it is composed of two Planes, the one exterior in the Iris and the other interior in the Uvea ; but both these Rings, external and internal, contract the Pupil, even to a very small Point or Opening. The Use of this Sphincter or muscular Circle, is to defend the Eye in too strong a Light, by contracting the Pupil, and admitting fewer Rays ; and thus it increases the coloured Part of the Eye. Both these muscular Rings have been lately discovered by *Ruyfch*, afterwards by *Raw*, and since by *Hovius*.

§. 521. But in the Uvea there is also a wonderful Contexture of Arteries form'd into *Rings* ', which from thence detach Branches,
even

even though these Arteries, from whence those Branches arise, formed before nearly the same wonderful Fabric in the Tunica Choroides. If now we consider this wonderful *Aparatus*², it will teach us, that the greatest Degree of Attenuation, must be here given to the most subtle Humours, and that the grosser Parts of those Humours are easily *retained*³.

¹ As we find muscular Fibres, which are some annular and others radiated, so there are also Vessels both orbicular and branched out like Rays which accompany the muscular Fibres; and these have been beautifully demonstrated by *Ruysch* and *Hovius*. Also together with the muscular or nervous Fibres, the Arteries likewise are detached in Rays from that Part of the Sclerotica which unites with the Cornea, and from thence they tend towards the Pupil; and likewise wherever there is a muscular Circle, there is another arterial one perpetually accompanying the nervous Fibres.

² These arterial Ducts arise from the Arteries which perforate the Sclerotica in four Places, and appearing like black Points in the Choroides, they terminate in reticular Plexus's extremely minute; by which the Impulse of the Blood is broke and its Particles attenuated, and at length being spread in the Tunica *Ruyschiana* and Uvea, they seem to seern the aqueous Humour by open Tubes, some thousands of times smaller than the least Blood-Vessels.

³ The grosser Parts are returned by Veins, which *Hovius* by his Injections has demonstrated to open into the aqueous Humour, which is this way continually absorbed.

§. 522. In the mean time that very thin *Membrane* ¹ which forms the Uvea (§. 519.), arising from the Circumference of the Choroides in the same Place (§. 520.), is also furnished with arched muscular Fibres, which embrace the rising, gibbous, annular Surface of the vitreous Humour, where it projects beyond the Circumference of the crystalline Lens: the fixed Point of these muscular Fibres is in the Beginning of that Circle of the Uvea round the Margin of the Cornea, from whence they arise; but their moveable Termination is in that Circle of the vitreous Humour which departs from the Crystalline Lens. These Fibres are more distant from each other than those in the Uvea; their intermediate Spaces or Intervals being filled up with a *black* ² Pigment or Colour: and here also there are Blood-vessels found distributed in the same Manner like those of the Uvea (§. 521.)

¹ From the Rim or Circumference of the Tunica Choroides and *Ruyschiana*, where they depart from the Cornea, arises that very thin Membrane, a thousand times finer, encompassing the vitreous Humour, but not covering the crystalline Lens. But from the Circumference of this thin Membrane arise nervous Fibres detached from the third and fifth Pair, and distributed like Rays on all Sides towards the crystalline Lens, being those which the ancient Anatomists call the ciliary Ducts; whereas *Ruysch* intends a different thing by that Name. By the Action of these Fibres the crystalline Lens is held firm or fixed in
the

the same Place, and when they are contracted they may press back the vitreous Humour, so as to thrust the crystalline Lens more forward, which will subside again when these Fibres are relaxed. These same Fibres continue on over the Margin of the crystalline Lens, to which they give that first or loose Membrane which is spread upon its Fore-side. (See §. 503.)

² The internal Surface of the Uvea is spread with the very blackest Pigment, which prevents the Reflection of any Rays from the outer Part of the Eye inwards; nor can any of the Rays pass to the Retina, which enter the lateral Parts of the Eye; for these are on all Sides stopped or suppressed by the black Pigment; so that none can pass to the Retina and extend their Action to the common Sensory, but what enter in a direct Course through the middle of the Pupil. If Nature had not furnished our Eyes with this black Pigment, the Mind would have perceived the external Figure of the Eye as in a Looking glass, instead of the Image of each Object. The like Blackness was also spread betwixt the crystalline Lens and the Sides of the vitreous Humour, to prevent any of the Rays from being reflected back out of the Eye; for every Ray which falls upon the black Pigment is suffocated and absorbed, and conduces nothing towards Vision. Hence it is that any Person may see his own Face in the Eye of his Companion, where being depicted it is reflected back; but if this same Reflection should have succeeded within the Eye, the like Image would have been seen by the Person himself without inspecting the Eyes of another.

§. 523. But the otherwise *flexible* vitreous Body or Humour, is contained in a most fine

Membrane of its own, connected on all Sides to the concave Surface of the *Choroides* ² by very minute Ligaments; being so slender or fine, that it is scarce visible, chiefly by reason of its extreme Pellucidity; yet this thin Membrane is perceptible, by the *distilling* ³ or dropping out of the Water, from the vitreous Humour, after it has been wounded.

¹ This vitreous Body is so flexible and free on all Sides, that when the Sclerotica is cut off, and an Incision made in the Choroides, it slips freely through, together with its entire Membrane, without affording Signs of any manner of Connection. But it is improperly called a Humour, inasmuch as it is a firm but flexible Body composed of thin Membranes and Muscles.

² These Ligaments from the Choroides are the ciliary Ducts, which arise from the Margin of the Choroides, in that Part where it forms the Uvea, and adhering to the whole Surface of the vitreous Membrane, they restrain the whole Body of it from collapsing into an aqueous Humour; they are on all Sides spread with a very black Pigment, and are called the ciliary Ligaments.

³ The vitreous Body or Humour, as it is commonly called, being taken out of the Eye, and put into Water not quite scalding, floats and coagulates therein without dissolving, and even without changing its Figure. If the same Body be taken whole out of the Eye, open'd by a very light sharp Instrument, and then suspended in the common Air over a glass Plate, upon wounding it with a Needle it will distil aqueous Drops continually, and the very thin Membranes remaining will by degrees quite vanish; the vitreous Body has therefore

fore a proper Membrane of its own, for otherwise it would have been dissolved in the Water, if it was not defended with some Covering; it also appears to be made up of very thin concentric Sacculi, each of which is filled with its proper aqueous Fluid, but communicating altogether, since by wounding one of them all their contained aqueous Humour is discharg'd; for if the contained Liquor stagnated in one common Sacculus, it would then be suddenly discharged, upon making an Incision thro' the external Membrane, whereas we see that it distils very slowly. That this Membrane is furnish'd with Vessels is highly probable, only they are so thin and pellucid that they cannot be view'd even by the best Microscope.

§. 524. In an Excavation in the middle of the lower and anterior Surface of the vitreous Humour is placed the crystalline Lens, free or moveable, and connected to the same by the vitreous Membrane (§. 523.) as well as by its own proper very thin *Membrane*¹; but these fine Membranes with their contained Bodies are so thin and pellucid, that they are quite seen through; and yet Reason teaches us that they must be furnish'd with their proper small *Vessels*²; and Experience demonstrates the same in the largest of Animals, the Whale.

¹ The crystalline Lens is seated in a Cavity impressed in the lower Part of the Surface of the vitreous Body, and coheres to the same vitreous Body by small Vessels, which I have been able to discern with my Eyes, but of so tender a Nature, that they are broke or destroy'd by a slight Pressure of the Hand; but the Rim or Margin with which

which the crystalline first touches the vitreous Body, is encompassed all round with the ciliary Ducts, which form a Circle or Ring, as *Ruysch* has demonstrated by his Injections. From this same Circle of the ciliary Ducts is expanded a Membrane, which covers and contains the crystalline Lens, that it might not be easily shook or agitated in the vitreous Body; that the Capsula of the crystalline performs this Office, is evident in the couching of a Cataract, when the Capsula being incised, the crystalline Lens slips out of its Place. The Surgeon skill'd in the Art of Couching, makes a Puncture thro' the Sclerotica, under or within the Rim of the Iris, at about the Distance of the twentieth Part of an Inch from thence, or rather at the Distance of two Lines from the Iris; as soon as the Sclerotica is perforated, and he sees that his Needle can move freely, he then directs it in such a Manner as to avoid touching the Iris, until he perceives the Needle through the Pupil; when the Needle is seen thro' the Pupil, he then tries whether or no it adheres to or draws the Iris, and finding it free, he turns the Point of the Needle inward, and with a gentle Force wounds the anterior Membrane of the crystalline Lens, and forces out the Lens down to the Bottom of the Eye. That this last Part of the Operation is necessary to be perform'd, they very well know who are skill'd in this Affair, whatever some of the Moderns may have wrote against this Opinion; for the Tunica Arachnoides of the crystalline Lens prevents it from subsiding on the aqueous Humour by its own Weight, which is greater than that of the aqueous Humour; this arachnoide Membrane covers the Lens before, and invests the vitreous Body behind.

The

² The crystalline Lens (which is a more just Denomination than that of crystalline Humour) is in Fish perfectly spherical; but in other Animals it is more or less flat or depressed, consisting as it were of two Segments of Spheres. If now the crystalline Lens of a human Eye is placed in warm Water, and you take off its Membrane by very fine Instruments, the whole Lens will appear divisible into an infinite Number of parallel Strata, each of which are made up by small Vessels complicated in a particular Manner; but each of these small Vessels are pervaded by their respective Humours, the Circulation of which is carried on even into the very Center or Body of the solid Lens. These Vessels seem to arise either from the ciliary Ducts, or from the vitreous Membrane. In the Eye of a Whale, the Rim of the crystalline Lens is encompassed with a hollow Ring or arterial Vessel, from whence small Roots are detached, even into the Beginning of the Lens. From hence it is evident, upon what minute Organs the Integrity of the Sight depends, which is one of the greatest of human Enjoyments. For if the Eye continues sound in other respects, and the Circulation of the Humours through the crystalline Lens only is disturbed, that Body will then be continually obscured with an Opacity, the Whiteness of which will be seen through the Pupil, so as to destroy or subvert the whole Sight.

§. 525. Lastly, The interior *medullary* ¹ Part of the optic Nerve, *perforated* ² in its Middle, enters the Bottom of the Globe of the Eye in such a Manner, that its *Entrance* ³ with respect to the Height of the Globe, is in its *Middle* ⁴; but in respect to the Breadth or transverse

transverse Diameter of the same, the Nerve is seated one third Part of the Diameter of the Eye nearer to the internal Angle. Hence the optical Axis does not fall upon the Entrance of the optic Nerve, but recedes a considerable Distance from thence towards the external Angle. The Medulla of the optic Nerve being thus enter'd into the Globe of the Eye, is immediately after expanded in the Bottom of it under the vitreous Humour, spreading on all Sides together with the larger Arteries which enter'd with it, and accompany every Point of its Expansion with their small Branches; it has also *lymphatic Vessels*^s, but in other respects resembles a soft Mucus, and is called the Retina.

¹ The Pulp of the optic Nerve is composed of the Medulla from the anterior Ventricles of the Brain itself, or from the Thalami Optici continued into the Eye; at entering which, at the opening of each Globe, they deposit first the Integument which answers to the Dura Mater, from whence it is derived to form the Tunica Sclerotica; it then deposits the Tunica Arachnoides, from whence results the Choroides; together with the Pia Mater, from whence arises the Tunica *Ruyschiana*. The Nerve being destitute of these Coverings, is then a naked Medulla or soft Pulp.

² This Perforation of the optic Nerve has been justly described by *Galen*, who is defended by *Eustachius*, in opposition to *Vesalius*, whose valuable anatomical Tables ought to be purchased at any Price. *Galen* first describes the nine Pair of Nerves, but says, that in the Middle of the optic Nerve

Nerve there is a Cavity, continued as it were from the Eye to the anterior Ventricles. This Discovery of *Galen* was afterwards confirmed by *Ruysch*, who esteeming the Preparations of Art more than Books, was not acquainted with the Fame of *Eustachius*. This Cavity in the optic Nerve is filled by a sanguiferous Artery, which being empty in the dead Body is drawn back, and leaves a bare Tube or Perforation. From this Artery are derived the Vessels which are dispersed through the Retina and vitreous Humour. Upon this Perforation of the Nerve depends that wonderful Experiment of *Mariot*, which we shall mention hereafter at §. 542.

³ When the optic Nerve has reached the Globe of the Eye, it is expanded on the internal Surface thereof, in medullary Rays or Fibres, and forms a true Membrane; so that the Retina is nothing more than the Medulla of the Brain itself expanded like a Membrane, that is, into a mucous Network. All this may be illustrated by Experiment in the Eye of an Ox; which ought to be taken entire out of the Orbit, and opening the Sclerotica by a crucial Incision, and then dividing the Choroides and Tunica *Ruyschiana*, the next that follows to these is a tender Mucus, almost like that of the Nose, of a whitish Colour, but little more consistent than a Fluid, and capable of being destroyed by the least Force. The convex Part of this mucous Membrane, the Retina, lies next to the Tunica *Ruyschiana*, and its concave Part towards the vitreous Humour; betwixt which two it is expanded throughout the whole Cavity of the Eye, even to the ciliary Ducts, and almost to the Margin of the Iris.

⁴ This Obliquity of the Insertion of the optic Nerves ought to be well remember'd. For it is commonly said by Anatomists, that the optic Nerve

Nerve enters the Middle of the Eye ; and in some Animals this is true, but not in the human Body. We ought to suppose first a Plane to pass through the Middle of the Axis of the Eye horizontally from before backward ; and thus the whole Eye will be divided into two Parts, upper and lower. Now in this Plane the optic Nerve enters the Eye, in its Middle with respect to upper and lower. But if we suppose the Eye to be divided by another Plane, descending perpendicularly thro' the former, the Eye will be divided into a right and a left half or Side : but then the optic Nerve does not enter the Eye in that Plane, but in the Middle of the interior half of the Eye, so as to be one third Part of the Diameter of the whole Eye distant from the internal Extremity of the Bulb, and two third Parts distant from the opposite Side of the Bulb, next the external Angle of the Orbit ; and therefore the Nerve recedes vertically, one sixth Part of the Breadth of the Bulb of the Eye, from the Plane, which cuts the Eye perpendicularly into two Halves. The Reason of this Mechanism seems to be as follows. The Middle or Center of the optic Nerve is blind or insensible, because there a considerable Artery enters the Eye ; but the Artery cannot see, for the Nerves only are the Organs of Sensation. If you inspect the Eyes of some Patients in a serene Air, there can be no sensible Defect observed, when at the same Time the Patient complains of seeing little Balls dancing. This arises from the lymphatic Arteries which cover Part of the optic Nerve, and are not capable of seeing. This being the Fabric of our Eyes, had the optic Nerves been inserted perpendicularly in the Middle of the transverse Plane, the parallel Rays coming from any Object placed before us, would have fallen upon this Artery ;
whence

whence we must consequently either not perceive the Object at all, or else see it as with a Hole in the Middle. To avoid this Inconveniency, Nature has inclined the Entrance of the optic Nerves nearer towards the Nose; and has thereby removed the blind Part of the Eye, so that it loses only that visible Point of an Object which is the least Necessary to be seen by both Eyes, and which may be always seen by one of them when there are two. Nor were the optic Nerves ever observed to deviate from this Obliquity of their Insertion. But in the mean Time it is to be observed, as we shall hereafter demonstrate, in opposition to *Mariot* and others of the *French*, that not the Choroides but the Retina, is the true and immediate Organ of Vision.

⁵ *Ridley* observed lymphatic Vessels in the Bottom of the Eye, distinct from the medullary Pulp of the Retina; which lymphatic Vessels are pellucid, and incumbent on the sensible Nerve, in such a Manner, that the Images of the Objects pass through them as through a Glass. When any of the red Blood passes into these Arteries in Inflammations, the Eye is in a Manner half blinded; and when they vibrate or beat, we see luminous Sparks in the Dark. If a young Man is ordered to look towards his Nose, and a Pressure is then made upon the Eye, at the lesser Angle of the Orbit, he will perceive a luminous Flame. Before an Apoplexy the Patient frequently perceives a luminous Flame or Sparks; and *Aretæus* observes, that the same Appearance precedes an Epilepsy. The like also is sometimes observed in other inflammatory Diseases of the Head, in a Phrenzy, &c. But when the Arteries are quite broke, a perfect Blindness follows, without any external Signs of the Disorder, which is then called a Gutta Serena.

§. 526. The Cavity or *Chambers* ¹ of the Eye formed before by the concave Surface of the Cornea, and behind by the convex Surface of the vitreous and crystalline Body, is *filled* ² with a thin, very pellucid and *brackish* ³ Humour, inodorous, soon exhaling, and soon *renewed* ⁴, preserving the flaccid Cornea equally *distended* ⁵ in its Convexity, supports on all Sides the *Uvea* ⁶ which is suspended in it; and being extremely fluid in the Time of Youth, it by Age passes through various Degrees of Thickness and *Opacity* ⁷, till at length it often becomes whitish in old People: it seems to *arise* ⁸ from the arterial Blood prepared in the Choroides, and more perfectly elaborated in the arterial Circles of the Iris, and in the vitreous Humour; and being farther attenuated in the smallest lymphatic Arteries which from thence arise, it continually transudes through open Ducts, seated all round the internal *Surface* ⁹ of the Cornea in the Iris, Uvea, vitreous Membrane and arachnoide Tunic of the crystalline Lens, opening into this Cavity; this same Humour is afterwards again continually *absorbed* ¹⁰ by the open Mouths of the lymphatic Veins, without leaving any manner of *Fæces* ¹¹ behind. For which Purpose of absorbing, the Ducts of *Nucke* ¹² and others are quite unfit, as will readily appear to any one after due Consideration. This Liquor therefore, continually supplied by these *tender* ¹³ Parts or Vessels, serves

serves continually to moisten, lubricate and retain these Parts in their due State of Pellucidity ; and even the Sinking or Collapsion of the Eyes in dying People, seems to infer that the subtle Spirits of the Nerves are also deposited into this Cavity.

¹ Betwixt the concave Surface of the Cornea, and the convex Superficies of the vitreous Humour and the crySTALLINE Lens, there is a Cavity, which is divided in the Middle by the Iris and Uvea into two Chambers, which communicate together by the Foramen of the Pupil. This last Cavity is quite filled full with the aqueous Humour. There are therefore three distinct Cells or Chambers in the Eye, like as there are three distinct Cavities in the Thorax. The first is the Chamber of the aqueous Humour, which is partitioned into two, the one anterior betwixt the Cornea and Iris, and the other posterior betwixt the Uvea and ciliary Ligaments.

² So long as a Person lives, this Cavity remains full and distended with the aqueous Humour ; but after Death it is continually wasting, and the Eye collapses ; infomuch that the Eye seems to be distended to its proper Degree, by the continual pouring in of the aqueous Humour by the *Vis Vitæ*.

³ This Humour is a little more consistent than Water, is pellucid in a healthy State, freezes by Cold, though it is more difficultly turned into Ice than simple Water : it is in some measure salt or brackish, as I have frequently tasted. It congeals with Spirit of Wine ; and therefore this Spirit seems to be improperly used in Diseases of the Eyes.

* This Humour is so soon renewed, that after extravasating the same by a Puncture, it will be restored again in the space of twenty-four Hours, as we are assured by Experiments. The Ancients were indeed not ignorant, that by perforating the Cornea, the aqueous Humour is discharged, and afterwards renewed again. This Observation was renewed by a some time famous Chemist, *Josephus Burroughs*, a boasting sort of a Person, who perished in a *Romish* Prison for writing against the Virginity of the blessed *Mary*. But he cloaked the Experiment under a Medicine, which he called the Quintessence of Cellandine prepared by Chemistry; one Drop of which Essence being distilled into the Eye, restored the aqueous Humour and the Sight. He performed his Experiments before the Physicians at *Amsterdam*: He perforated the Cornea in a Dog, and suffered the aqueous Humour to be discharged, insomuch that the whole Eye collapsed; and after dropping in this Liquor, bound up the Eye, and left the Animal in the Care of the Physicians. The next Day he undressed the same Eye in the Presence of the Physicians, when it appeared full and fair like the other Eye, as if it had not been injured. But about the same time it was found by other Experiments, that the same Event would follow, even though nothing was poured into the Eye. The expert *Redi* tried the Experiment upon all Kinds of Animals, by wounding the Cornea near the Iris, and pressing out the aqueous Humour, by which the Animal became blind: but by the Application of a Fomentation with Milk for forty-eight Hours, the Wound appeared healed, and the Eye filled with its aqueous Humour; whence it manifestly appeared that there are Ducts in the Eye, from whence the aqueous Humour is continually poured
into

into its proper Cavity. There was a Lad of a noble Family, which at that time had the chief Government in the Republick, who in play had a Stone flung, by which the Cornea was wounded, and the aqueous Humour discharged, so that the Eye collapsed. I being called at that Instant of Time, ordered him to be bled plentifully, and to observe a perfect Abstinence; and after dropping into the Eye some warm young Pigeon's Blood, without any other Quintessence, carefully bound up the Eye, and so left it for the space of forty-eight Hours; after which time, in removing the Dressings, the Eye appeared entire and full, the aqueous Humour being perfectly restored. Upon this Experiment is founded that bold Operation of *Woolhouse*, in which the Cornea is perforated to extract Matter or Membranes lodged in the aqueous Humour.

⁵ The Eye would not be capable of seeing, unless the whole Cornea was equably distended and flexible outward; for the Eye can only be expanded into a Sphere, when the extending and resisting Forces are equable in every Point. This was therefore the Reason why Nature has extenuated the hard Sclerotica into the thin Cornea, and sustained it by the aqueous Humour, which perpetually urges the Cornea forwards and outwards, by the vital Force with which it is impelled through its proper Ducts. For when that Force ceases, the Cornea continually shrinks or collapses, the Colours of the Rainbow are observed in the Eye, and the whole Person becomes lifeless.

⁶ When the Head is inclined forward, the Iris would approach towards the Cornea; and when the Head is inclined backward, it would approach towards the vitreous Humour, if it was not sustained on each Side by the aqueous Humour: for by

this Humour it is kept in such an Equilibrium, that there is no greater Inclination of it to one Side than the other, in all manner of Postures. If the aqueous Humour is deficient, as in People who are dying, in that Case the Figure of the Eye is changed, the Iris collapses backward, and the Pupil dilates extremely large.

7 When this Humour becomes opake, it forms the first Species of the spurious Cataract. In this Case the whole Eye appears whitish externally, and the Whiteness covers the Iris and the Pupil, so as to destroy the Sight, which can be restored by no Artifice; as we may often observe in old People. It is not difficult to distinguish this Disorder from the true Cataract; for in this last, the Cornea and Forepart of the Eye, with the Iris, suffer no visible Alteration, but a Whiteness appears behind the Pupil, namely, an Opacity of the crystalline Lens. If *Woolhouse* had considered this Difference as he ought, those who have wrote against him, with *Heister* and others, might very easily have reconciled the Difference of the two Kinds of Cataracts; namely, an Opacity of the aqueous Humour, and a Disorder of the crystalline Lens. Lastly, There is another Disorder of this Humour when it is deficient, or not separated in a due Quantity to suspend the Pupil, which therefore collapses backward.

8 But as to the Origin of this Humour, it ceases to be any longer an Opinion or Conjecture; after it has been sufficiently demonstrated by Experiments. For all the Parts here mentioned are full of most minute Vessels, the smallest of which seem to exhale a most thin Vapour, every Particle whereof is a volatile Spirit, and wonderfully expansive; but being collected together and confined, these Particles are converted into a kind of
Water.

Water. Thus common Water is by the Force of Heat rarified into a Vapour quite volatile, and by the Force of Cold is again condensed into a true Water: but we may fetch an Instance of this still nearer in our Breath, which by the Cold is condensed into aqueous Drops.

9 The whole concave Surface of the Cornea, with the Convexity of the crystalline Lens and vitreous Body, together with the Surface of the Iris and Uvea. From this large Extent of Surface is separated a thin Water, which continually moistens the most minute radiated and orbicular Muscles of the Iris, and prevents their Concretion. And that the same Humour is secern'd from the Cornea, we know by Experiment: for if the Eye-lids be held from winking, and the Cornea wiped dry in a healthy Person, soon after a thin Liquor will appear to transude through the dry Cornea. Thus *Peyerus* has demonstrated by solid Experiments, that all the Membranes in the human Body perspire.

10 If this Humour was not to be absorbed, being perpetually accumulated by the Arteries without returning by the Veins, it would cause a Dropsy of the Eye, or produce the *Oculus Elephanti-nus*, in which the Eye is distended forward in a very unsightly manner; but it is distended forward, because behind there is the Resistance of the bony Orbit, which obliges the accumulated Humour to exert all its Force in distending the Cornea. If the Cornea is perforated with a very small Needle, the aqueous Humour discharges itself through the Puncture; but then the Water is soon renewed again, and the frightful Tumour of the Eye returns.

11 It may perhaps seem wonderful to one who duly considers, that the Humours continue limpid

without any Opacity in the Eyes of a Person eighty Years old. But it is more wonderful to one who considers that the aqueous Humour is opaque in new-born Infants by a kind Provision of Nature, that their tender Eyes might not be molested, or too violently affected by the Light, to which they have not been accustomed. It is well known by every body, that Kittens and Puppies are blind at their Birth; but this is true not only in these Animals, but in all Animals in general; namely, that they are destitute of the Office of their Eyes. In the mean time, by Degrees, the aqueous Humour deposits its white Colour, and becomes more transparent, continuing ever afterwards limpid without depositing any Sediment, or forming any Spots; which is indeed wonderful, and not to be imitated in any other Humour.

¹² But *Hovius*, as well as *Nuck*, pretends to have discovered the true Sources or secretory Vessels from whence the aqueous Humour is derived. It is sufficiently demonstrated from the Observations of those Anatomists, that these Vessels are at first large and sanguiferous; but that from the manifest other pellucid Vessels, from whence the aqueous Humour is derived after it has been attenuated in the Vessels, passing through the livid Points of the Sclerotica and Choroides; and being afterwards farther attenuated and subtilized in the *Tunica Ruyfchiana*, it at length distils through the most minute aqueous Ducts. But so subtle a Humour could not possibly be separated by any Vessels but those of the ultimate Series, or smallest decreasing Arteries, which exhale their contained Juices. At least we may be certain, that so long as we are capable of seeing these Vessels, we are sure that they cannot be the Fountains from whence the aqueous Humour is derived.

Namely,

¹³ Namely, the very small Muscles of the Iris, Uvea, and crystalline Lens, which require to be continually moistened in a Bath, lest they should concrete together, and become opake, and that they might continue constantly and equably flexible and free for Motion.

§. 527. The solid crystalline Lens, convex or *spherical* ¹ on each Side, is composed of an infinite Number of fibrous, and very pellucid *spherical* ² Strata or Segments, strictly united to each other, so as to form a transparent *Body* ³ much denser than the aqueous, or even than the vitreous Humour, which is seated in that Part of the Eye, where the Axis of Vision passes through its Center, assisting to form the same Axis, and lying nearer to the Cornea than the Retina, being made up of an infinite Number of small Vessels, as appears from the shrinking and Loss of Weight which it suffers by *drying* ⁴; it is therefore improperly called a Humour, since it is a Solid furnished with Vessels from those which are *continued* ⁵ to its including Membrane.

¹ The Surface of the crystalline Lens is perfectly equable; but when it is split in two, it has unequal Sides, and multiplies Objects in the same manner as when we look through a Multiplying-Glass, which has many Sides or plain Surfaces, repeating the Image of a single Object as often as the Lens is divided into distinct Planes. An Instance of this rare Disorder has fallen under my own Observation.

² If the Cryſtalline Lens be well cleaned and held in ſcalding Water, there appears a white, fibrous and opaque Cruſt upon its Surface; and if that be taken off ſlowly and carefully by a Needle, and viewed by a Microſcope, it appears to divide into an infinite Number of thin Membranes concentric to each other; but each connected to the other by a kind of reticular Plexus, as they riſe one under the other. Thus Children know how to peel off the opaque Membranes or Coats from the white Eye of a boiled Codfiſh, till at laſt there remains a ſmall pellucid Spherule, which they call a Pearl.

³ The cryſtalline Lens is in ſome meaſure render'd opaque even by Death, but much more ſo by ſcalding Water. This is therefore the manifeſt and moſt frequent Cauſe of Cataracts, which ariſe from the Application of Medicines too hot for the Eyes, or from an Inflammation of the Eye preceding. For ſo ſoon as the cryſtalline Lens is opaque, the Diſorder is termed a Glaucoma, which may be eaſily known from the Appearance of a white Spot in the Middle of the Patient's Eye, behind the Pupil.

⁴ Thus *Hovius* experienced, that the cryſtalline Lens ſuſpended in the open Air contracted, and grew lighter every Moment, till at laſt it ſhrunk up to a dry callous Membrane. It is therefore replenished with Veſſels, each of which are pervaded by their reſpective Humours. I made an Experiment for this Purpoſe upon the cryſtalline Lens of a Hog: after abrading the firſt Membrane, a ſort of Liquor was diſcharged, which being wiped up with Lint, more Water followed in a leſs Quantity upon abrading the next Membrane, and ſo on.

Namely,

⁵ Namely, those continued from the Ring in which the ciliary Ducts terminate; which Ring was first demonstrated to be vascular by *Ruyfch* in a Whale, whatever *Hovius* may say to the contrary; from which Ring an infinite Number of small Vessels pass into the crystalline Lens for its Nutrition, and for conveying the Humours which continually circulate as long as we live.

§. 528. The vitreous Body or Humour is extremely pellucid, flexible, and more dense than the aqueous, being *vascular* ¹ on all Sides, as we are taught by the distilling and drying up of its Humour after wounding the Vessels and including Membrane; and therefore there is doubtless a continual Circulation of its Humour. When the arched Fibres (§. 522.) are *contracted* ², the Ring or Circumference of the vitreous Humour round the crystalline Lens is depressed, and therefore its Middle becomes elevated, and thrusts the crystalline nearer to the Cornea, and further from the Retina; but when these Fibres are relaxed, the Sides of the vitreous Body recover their former Situation, and the Swelling of its Middle subsides, by which means the crystalline Lens is brought nearer to the Bottom of the Eye to perform its proper Office. The vitreous Body is therefore softer than the crystalline Lens, that it might be susceptible of this Change of Figure.

¹ We find that the vitreous Body grows up from that small Bulk which we observe in the Foetus, continually and equably augmenting on all

all Sides to that Magnitude which we observe in the Adult : whence it is evident, that it must be furnished with Vessels, but which are so small and pellucid that they escape the Sight. They seem to arise from the circular Rim, which has so many arterial Radii as there are Muscles, which is demonstrated to us by the Injections of *Ruyfch* : or it has Arteries or Veins which are pellucid from the Membrane of the vitreous Body which is incumbent on the Retina.

² The vitreous Body fills the whole Eye from its Bottom where the optic Nerve enters, even to the Backside of the Uvea. It is convex on all Sides, and furnished in the Middle of its anterior Convexity with an Excavation or Cavity, into which the crystalline Lens is received ; but round that Excavation there is a Sort of protuberant Ring. But the ciliary Ducts are spread upon the convex Surface of the Forepart of the vitreous Body, and are inserted into its Membrane ; and therefore when they contract or become shorter, they depress or thrust back the vitreous Body on every Side. But behind there is the Resistance of the bony Orbit ; and therefore the vitreous Body will protuberate in that Part where there is the least Resistance, that is, in the Middle of its anterior Surface, which contains the crystalline Lens, and which is not compressed either by the Muscles or the hard Sclerotica. It therefore follows, that the vitreous Body being pressed back by the Contraction of the ciliary Ligaments, will thrust the crystalline Lens forward towards the Cornea. And this is the Reason why the vitreous Body is more flexible than the crystalline : nor could the crystalline Lens itself be thus moved, if it was not more hard and dense than the vitreous Body. There was the greatest Necessity for this Mechanism

nism in the Eye, to render it capable of seeing distinctly both near and distant Objects.

§. 529. The Eye thus formed (§. 515 to 529.) and seated in the bony *Orbit* ¹, there receives in its Forepart the *Tunica adnata*, which is loose, moveable, and derived from the *Periosteum* of the external Margin of the Orbit; and this Membrane being pellucid and full of *Vessels* ², is spread over the whole anterior Surface of the Eye, the Bulb of which is by this means fastened and secured without the least Injury to its free Motion.

¹ This Membrane arising on all Sides from the Bones of the Orbit, appears white, and is spread from the Forepart over the whole Surface of the Globe of the Eye, covering the whole *Sclerotica*, and extending itself as far as the Iris, it there becomes very thin and pellucid, and is in that manner extended over the *Cornea* itself, as the exquisite Anatomist *Amannus* demonstrated thirty Years before, by separating the whole *Tunica adnata* from the *Sclerotica* in the Eye of a Calf. There is also a Tumor of the Eye termed *Hypopyon*, or a Collection of Matter betwixt the *Sclerotica* and *Tunica adnata*; which last is in that Case to be punctured to discharge the Matter, and then the Disorder may be cured in a little Time. This Tumor sometimes creeps or spreads over the *Cornea*, so as to demonstrate apparently, that the *Tunica adnata* extends itself over the same. Nor yet does the firm Adhesion of this Membrane any way impede the free Motion of the Eye. It is therefore a false Notion which is commonly entertained, that the *Tunica adnata* terminates in a Circle,

Circle, as if it were cut off from the Cornea, which is supposed to remain naked.

² The Inspection of the Tunica adnata leads us a great Way into the Knowledge of Diseases. When there is a small or incipient Inflammation in the Brain, this Membrane always looks red; and therefore it may be useful to inspect it with a magnifying Lens. We have now considered all the Coats of the Eye. The outermost of which is the Tunica adnata, after which follows the Sclerotica, which becoming pellucid in the anterior Part of the Eye, is there termed the Cornea. Under the second or hard Coat of the Eye lies the Choroides with its interior Lamella, called from its Discoverer Tunica *Ruyschiana*. But from the Choroides and Tunica *Ruyschiana*, receding from the Sclerotica and Cornea, arises a sixth Coat, namely, the Iris, the posterior Face of which is called the Uvea. The eighth Tunic in the Eye is the Arachnoides, arising from the ciliary Ducts, and spread over the crystalline Lens. The ninth Tunic is that of the vitreous Humour arising from the Tunica *Ruyschiana*. The tenth and last Coat is the Retina, namely, an Expansion of the Medulla of the optic Nerve. We have also seen that the Eye is divided into three Cavities or Chambers; the first of which is partitioned into two, the one Anterior and the other Posterior, containing the aqueous Humour betwixt the Cornea before, and the crystalline Lens behind, partitioned in the Midst by the Uvea and Iris, the former looking towards the Backpart of the Eye, and the latter towards the Cornea. The second Cavity is that which contains the crystalline Lens, which may be conceived as a void Space, by supposing the crystalline Lens to be taken out. The third and last Chamber of the Eye, is that which contains the
vitreous

vitreous Body. So that all these Chambers or Cavities being absolutely filled, there remains not the least Vacuity in the whole Eye. The anatomical Demonstration of the whole Eye and its several Parts, is owing chiefly to the Industry of those, who have dissected the Eyes of the largest Animals, as the Elephant and Whale, having first accurately injected its Vessels, and then made a careful Dissection of the several Parts, after the Manner of *Ruyfch* and *Raw*.

§. 530. In the next Place there are four *Muscles* ¹, which arising *fleshy* ² from the Circumference of the larger Foramen in the Bottom of the Orbit, ascend round the Bulb, about the Middle of which they become tendinous, and are in that Manner inserted into the Sclerotica, to which they firmly adhere, and serve to *elevate* ³ or depress the Eye, draw it out or turn it towards the Nose, fix it steady or turn it round, compress or elongate the same, according as they act either *together* ⁴ or alone; and conspire with each other towards the several Motions of the Eye. Besides these four strait Muscles of the Eye, it has also two oblique ones, the uppermost of which, the *obliquus superior* ⁵, arises fleshy from the lower Part of the Orbit near the Musculus Atollens, and forming a fleshy Belly in its Progress, it is at length changed into a round Tendon, which passing through a cartilaginous Pully in the upper Part of the Margin of the Orbit towards the Nose, it passes back again from thence into the Orbit, and is inserted

serted into the Bulb of the Eye, in the middle Part, betwixt the Entrance of the optic Nerve and the Insertion of the Musculus Atollens; and its Action is to turn round the Globe of the Eye about its Axis towards the Nose, to draw it out of the Orbit, and at the same time to direct the Pupil downward, and by that means the Eye is so disposed as to be capable of seeing things which lie near it in the Face, or upon the Nose below itself. But the *obliquus inferior* ⁶ Muscle arises fleshy from that outer and lower Part of the Orbit, where the Bones are joined together, and is inserted with its Tendon betwixt the abductor Muscle and the optic Nerve; it serves to turn round the Bulb of the Eye towards the external Angle of the Orbit, to direct the Pupil the same Way, and at the same time to turn it upwards, being capable of drawing the whole Eye out of the Orbit. But if both these Muscles act *together* ⁷, they fix the Eye fierce and protuberant out of the Orbit, and render it capable of discovering any thing injurious that lurks near it; but by suspending the Eye, they also render it very easily susceptible of the Motions of the four strait Muscles. But we here likewise particularly meet with a Quantity of soft Fat, placed under the convex Part of the Sclerotica, and betwixt the Foramen of the bony Orbit, placed there for transmitting the optic Nerve, and to thrust out the Muscles from the Bulb of the Eye, and to a considerable Distance from the optic Nerve.

1 In order to Vision it was necessary either for the Eyes to be moveable, or else the Head must have been moved perpetually in looking about. Nature has used a threefold Mechanism in the Eyes; making them in some Animals moveable, and in others fixed, but assisted by other means. There are some Animals which have their Eyes turning round as it were in the Extremities of their Shoulders or Arms, of which Kind is the *Zygæna*, a frightful Animal of the Dog-kind, which from its terrible Aspect is usually called *Meertefel*, in which Creature the Eyes are not placed in the Head, but in the moveable Shoulders near the Head; and in hunting its Prey, these Eyes are elevated out of the Sea, and directed every Way. Thus also Snails have their Eyes placed as it were upon their Horns as upon moveable Sticks. 2. There are other Animals again which have their Eyes fixed and immoveable, and in these the Eyes are very numerous. Of this Nature are Spiders, a very watchful Kind of Insect, in whose Head or Back there are eight or ten immoveable Eyes. 3. There are others which have the Eyes fixed in a certain Part, but so as to be moveable by Muscles, as we observe in most Kinds of Animals, and in ourselves. But among this last Class of Animals, some are capable of thrusting the Eye out of the Orbit, and others are not at all capable of that Action. Among the first Class are all the horned Tribe of Animals; and among the latter are included the human Species. The horned Tribe of Animals have seven Muscles belonging to the Eye, which occasioned *Vesalius*, being destitute of human Bodies, to reckon a seventh Pair of Muscles belonging to the human Eyes, which can be only found in Brutes. But we are here speaking only of the external Muscles
of

of the Eye, having before considered the internal Muscles which dilate the Pupil, and contract the same, seated before in the Iris, and behind in the Uvea, as a Sphincter to the Pupil, to which add those which move the crystalline Lens, namely, the ciliary Ducts or Ligaments.

² They are fleshy in the back Part, but become tendinous forward under the Tunica Adnata, where they are expanded like Radii almost as far as the Cornea; that they are extremely moveable may appear, inasmuch as they have Nerves from almost half of all the Pairs; for the second Pair of Nerves serves for the Sense of the Eye, but the third, fourth, fifth and sixth Pair send Nerves for the Motion of the Eyes.

³ The Musculus Superbus elevates the Eye, the Humilis depresses it, the Indignatorius draws it from the Nose, and the Bibitorius draws it to the Nose; which Muscles continually operate, and keep the Eye in a Plane parallel to the Nose, unless there is some Blinking or Defect in the Eye.

⁴ When all these Muscles act together with an equable Force, they draw the Eye into the Orbit; but as they all belong to the Sclerotica, and do not extend to the Cornea, it follows, that this last will remain unmoved, while the rest of the Globe of the Eye is drawn inward; and by that means the whole Eye will be in some measure elongated, to render it capable of seeing Objects which are very near to it. *Perrault* indeed wonders how four Muscles placed round a Sphere distended with Liquor, can press it so as to change its Figure and render it longer. It must be confessed indeed that this Change is but small, but yet the Cornea seems to be changed into an Arch of a lesser Sphere, accommodating itself so to the Eye, as to give a greater Refraction to the Rays.

⁵ The Obliquus superior or Trochlearis Muscle, arising from the Bottom and internal Surface of the Orbit, near the Origin of the Superbus, ascends over that last Muscle, and inclines towards the Nose and lateral Part of the Orbit, (but not towards the Middle of the Side of the Orbit like the Recti Muscles) where there is a small Notch perceptible in the Margin of the Orbit, and passing through a cartilaginous Ring, it is from thence reflected obliquely backward into the Orbit, and inserted in the Middle of the upper Part of the Globe of the Eye, betwixt the Entrance of the optic Nerve and the Musculus atollens. When this Muscle acts alone, it draws the Middle and upper Part of the Globe of the Eye forward out of the Orbit, and upward towards the Nose, and at the same time it turns round the Eye about its own Axis; so that it seems to change the extreme Point of the Axis of Vision, and turn it towards the Nose. Its Action is therefore, 1. To draw the Eye out of the Orbit towards the Nose. 2. To turn the same round about its Axis. To this Muscle is sent the whole fourth Pair of Nerves. There was a certain epileptic Patient, who always saw Objects double, because this Muscle was paralytic, and overcome by the stronger Power of the abducent Muscle.

⁶ The lower oblique Muscle is less than the former, but broader. It arises from the outer and lower Part of the Orbit, or from the internal Angle at the Bottom of the Orbit, where the upper Jaw-bone joins with the Side of the Orbit, arising fleshy from a Cavity there of its own, perceptible by the Finger in a dry Skull; and then entering the Orbit, it proceeds obliquely to the middle and bottom Part of the Globe, and is inserted betwixt the abducent Muscle and the optic Nerve. It

draws the Eye towards the posterior and lower Part of the Orbit outwards, and turns the Pupil upwards and towards the Nose; that is to say, it turns the Eye round upon its own Axis, and at the same time draws it out of the Orbit towards the Nose, so as to render it capable of seeing the Eyebrow above the Nose. And this is the proper Use of this Muscle when it acts alone.

7 When both these Muscles act together, the one of them draws the Eye out of the Orbit downward, and the other upward; by which means these Muscles destroy the Action of each other, as far as they are Rotators of the Eye, by their acting in a contrary direction; at which time they exert all their Force in drawing the Eye outwards, so as to render it protuberant; by this means therefore they render the Face fierce, terrible and cruel, which Painters well know, as they express these Passions of the Mind by such a turgid Position of the Eyes; and which we ourselves constantly perceive in People who are in a Rage with Anger, and eager after Revenge. 2. Also when these Muscles act together, they draw the whole Eye towards the Nose, that it may be better able to distinguish Objects. This Action is also observable in those who are fighting or striving for their Lives, as in Duelling, when each is very intent upon the Motions of his Antagonist. But when the recti Muscles of the Eye act together, we do not see near Objects. 3. *De la Hire* well observes, that the Eye of a Person or other Animal in a great Fright is fixed protuberant out of the Orbit, so that the Eye may be easily determined towards any Part which is intended to be observed by the Action of any of the recti Muscles. The ancient Statuaries very well expressed this Action in their Figures of *Lycaon*. This Action of the oblique Muscles is
so

so manifest from their anatomical Structure, that one would wonder how some Gentlemen of Note can in the least doubt it.——In the human Species, the Action of these Muscles is sufficient; but in the horned Tribe of Animals which feed from the Ground, the whole Bulb of the Eye is in a manner contained in a muscular Case or Shell, which makes the seventh Muscle of the Eye; by the Contraction of which, the Eye is thrust forward out of the Orbit. And this Action of the Eye we observe in the Ox, when he is enraged and threatens an Attack, while his Head is depressed and his Tongue licks the Ground; for he then thrusts out his Eyes almost a Finger's Breadth out of his Head, and continually taking Aim, strikes and levels his Enemy with a greater Certainty by his Horns. In *Spain* there are frequently Bulls fought with Men, who having received their Pardon enter the Ring, and approach towards the enraged Bull: and here the Champion places all his Safety in observing the Eyes of the Beast; for as soon as he perceives them begin to protuberate, he leaps on one Side, and strikes his Dagger betwixt the Horns of the Bull, who by that Means falls a Victim. This same Muscle fixes the Eye steady in Brutes, that they can look longer upon the same Object. *Vesalius* has falsely described this Muscle, as if it belonged to the human Eye; and, what is worse, he endeavours to defend it against *Fallopious*. Lastly, In Birds whose Eyes are placed in their Head laterally, and who scarce at all look directly downwards towards their Beak, there is a like muscular Case, which thrusts out the Eye that it might look directly downward towards the Beak, so as to discern their Food or Prey. But this in Man is performed by a slight Motion of the Head. Otherwise the Eyes of Birds are fixed, and cannot turn

every way whence they are obliged to be continually turning their Head about towards the Object at which they look, or towards their Prey, after which they are in search. In the *Facies hypocritica*, the Fat being all consumed in the Orbit, the Eyes are sunk and rigid, insomuch that the Patient is obliged to turn his whole Body towards any Side or Object at which he looks.

§. 531. But in order to determine the Manner and Seat of Vision, it will be necessary for us to add to this Structure of the Eye, (§. 508 to 531.) what is demonstrated to us in this respect by the Principles of *Optics*¹, *Dioptrics*², and *Catoptrics*³; a Compendium of which we are therefore to introduce here, chiefly from Sir *Isaac Newton*⁴, whose deep Penetration in mathematical and philosophical Matters, seems to have exceeded the utmost Limits of human Understanding.

¹ Optics is that Part of experimental and mathematical Philosophy, which teach us the Laws by which the Rays of Light spread from a radiant Point, or are reflected back from an opaque Point, or else pass through an homogeneous Medium. It may be termed the Doctrine of Vision in its greatest extent. But by mathematical or experimental Philosophy we understand that which leads us to the Knowledge of Bodies by Experiments.

² Dioptrics is that Branch of the Science of the Vision, which teaches the Laws by which the Rays of Light pass through pellucid Mediums of different Densities, and are changed in their Course by those Mediums. It is so called from *Dioptron*, a Hole to look through.

Catoptrics

³ Catoptrics is that Part of the Science of Vision, which teaches us the Laws by which the Rays explained by Optics fall upon an opaque Body, and are from thence reflected so as to form the Image of the Object. It is so called from Catoptron, a Looking-glass.

⁴ Before Sir *Isaac Newton*, all the Writers of Optics were in an Error; and although Authors pronounced that Colours were inherent in Bodies, yet none sufficiently explained the Thing: but Sir *Isaac Newton* first stepped out of the common Road, and considered Light in itself, and Colours as contained in Light, with their several Compositions and Divisions; all which he has comprised in that for ever to be esteemed Volume, his *Optics*.

§. 532. *Light* ¹ being an aggregate ² or Mixture of all Colours, *every way* ³ diffuses its Rays ⁴, which are extremely *subtle* ⁵, but yet are *compounded* ⁶ of all Sorts of Colours; hence therefore Light is divisible into several simple Colours, which being collected together or separately, make various other Colours, but being all combined together form a most splendid Light or Brightness like that of the Sun: and these Rays come from a lucid Point as from a Center, and spread from thence in right Lines through an uniform Medium towards every Point, passing through pellucid Bodies at the same time, and all in an insensible *Space* ⁷ of time; but they strike against and are reflected from opaque Bodies, so as to return from every Point towards the Cornea of the Eye in the Shape of a Cone, whose Apex is the lucid Point, and its Basis the Cor-

nea itself, provided there is no Obstacle interposed betwixt the lucid or radiant Point and the Cornea.

¹ Light is an Assemblage of small Particles emitted to the Eye from lucid Bodies, by which we are enabled to see them and other Things. If the Sun only was absent, and all the other Bodies in the Universe were to remain the same, the Eye however well formed, would not be capable of discerning any thing. Light we therefore call that Body, so little known to us, which enables us to see, being the same with regard to us, whether it comes from the Sun, the Moon, a Candle, Fire, or the like.

² A Colour is something seen by Light, for we can see nothing which has not some Colour. Vision is therefore Light, and Colours are the Species or Kinds of Light. *Euclid*, the Prince of those Philosophers who search after true and distinct Notions of Things, well defines a Surface to be the apparent Face or Limits different from the Thing itself; so that we see nothing of the real Object. Colour is therefore the Image of the Thing seen, and Light an Aggregate of all that is visible in the Universe.

³ If all the Walls and Roof of a dark Place are filled with Eyes capable of seeing, and then a Light is placed in the Middle of the Chamber, all those Eyes will see the Light, and at one and the same time. Therefore the Thing which is seen spreads itself every way upon the ambient Surface of the Object. Let there be a very small red Spherule in a Chamber, every one present will see the same Sphere, and yet no one will see the same Rays which the other sees, but each will receive a different

rent Portion of the Sphere of Rays which are sent towards him. Hence therefore the visible Rays or Images of Objects are spread from them equally on all Sides.

⁴ By the Name of Rays we term those Images of Objects which are infinitely divisible.

⁵ Let there be a Place extremely dark, in the Wall of which fix a thin Plate of Gold, perforated by the Point of the smallest Needle ; and to this Aperture within-side, let the Eye be applied in its healthy State, it will in that Case see as distinctly the Trees, Houses, and other Objects, as if it was placed in the open Air : and therefore all the visible Points from so many and so different Objects, pass through so small an Aperture. Hence therefore the Rays of Light exceed in Subtlety even the Power of Imagination itself.

⁶ All Philosophers have allowed what has been hitherto said concerning Light. But we now come to those Properties which have been discovered in Light by Sir *Isaac Newton* ; namely, that Light is not a similar Body, as was commonly supposed ; but that each Ray of Light is composed of seven other Rays, which joined together form a splendid or shining Point or Spot, a thousand times brighter than Whiteness, such as arises, for Example, from the Deflagration of Nitre with Sulphur. But when such an entire Ray of Light is split, it separates into seven distinct Rays ; one of which is Red, the other Orange coloured, the fourth Yellow, the fifth Green, the sixth Blue, and the seventh Violet ; namely, the seven primitive Colours : all which were present in the single Ray of Light, but by falling upon different Objects are separated from each other, and produce different Colours. But from the Combination of these primitive Colours arise an infinite Number

of mixed Colours, according as the first is combined with the second, third or fourth, or the second with the third, fourth or fifth, &c. From these seven distinct Rays therefore many thousands of Colours may arise barely by combining them in all manner of Rays. These simple Rays, as they are supposed to be, may be yet simple only as to Sense, and in reality compounded of other more subtle Rays, from whence again may properly arise an infinite Diversity of Colours.

7 When the Rays of Light pass through a Medium perfectly transparent, and without any Resistance, they pass on absolutely in a right Line, insomuch that the Rectitude of every thing is judged of by the Line of Sight. But in the Atmosphere the Rays of Light do not pass on in a right Line, as they proceed through a rarer Medium above to a more dense Medium below, whence it is that the Rays of Light are variously inflected in the Air. Yet we call them strait Rays which enter the Eye in a right Line from the Object, whence they were last reflected. Through the same uniform Medium, these Rays pass through an infinite Space in the smallest Interval of Time. For what is objected by the celebrated *Danus* against the immediate Continuity of Light from the *Satellites* of *Jupiter*, is since found to be without Foundation by the later Experiments of *Cassini* the younger. But we are convinced of it by a more simple way of reasoning, for we immediately perceive the Stars as soon as we open our Eyes, notwithstanding they are so many thousand Semidiameters of the Earth distant from us. It is an astonishing Argument of the Divine Wisdom, that we should thus be made capable of perceiving the Stars, though separated from us by such an immense Distance. But with respect to hearing the

the Laws are very different; for no Creature would be capable of any Rest or Silence, if Sounds were not required to pass through a determinate Space to us, in order to be heard. Nor is it sufficient to turn the Head aside, in order to exclude Sounds; nor can we so easily close our Ears as our Eyes, which are so contrived, that we can admit more or less Light at pleasure.

§. 533. The same Rays of Light approaching near to more dense Bodies, are *incurvated*¹ or turned out of their direct Course, some more and others less; and thus they are *separated*² from each other, reflected back to the Eye, and give the Sense of different Colours which are falsely ascribed to the reflecting or refracting Bodies, any farther than as the Surfaces of those Bodies separate the different coloured Rays from each other. This *Reflexion*³ is therefore various, according to the Variety of Colours in the Rays of Light itself; but yet in their Reflexion the Rays return in the same reflected Angle as that of their Incidence, with regard to a Perpendicular erected at their incident Point, nor is there any other Alteration here perceived.

¹ When the Rays of Light pass from a rarer Medium to a more dense Body, they are attracted by that Body by the great Providence or universal Law of Nature; for without this Property of Light we should be capable of seeing nothing but lucid Bodies. But the Rays are attracted most, when they are nearest to the virtual Surface of the Body itself. If the Rays of the Sun were attract-
ed

ed by the Earth, as soon as ever they were sent out from the Sun, there would arise an incorrigible Confusion in our Atmosphere, nor would there be any such thing as a right Line. This Attraction we know is performed, 1. Towards all denser Bodies, to which the incident Rays are more or less incurvated. 2. Towards every inflammable Body. 3. Towards certain diaphanous Bodies, such as Island Crystal.

² In reality we neither see the Body nor its Surface, only the Rays which return from the Body : but the different Surfaces of Bodies occasion one kind of Rays to be reflected more than another ; and thus scarlet Cloth bears that Name, because it reflects only the red Rays, while the other six Kinds of Rays are absorbed. Light itself cannot therefore produce the Diversity of Colours, since it is most equally distributed to all Bodies.

³ Let a Perpendicular be raised upon the plain Surface upon which the Ray falls, and let the Ray fall upon the Surface in an oblique Line, that Line with the Perpendicular will form an Angle : in the next place, let the Ray be reflected back ; in that Case the Angle of Reflexion intercepted betwixt the oblique and perpendicular Line, will be equal to the Angle of Incidence. But when a Ray falling upon any Body is reflected back from thence to our Eyes, it seems to the Mind as if it came from a Point as remote as the Body from whence it was first emitted. I have frequently taken some Pains to explain this Appearance. Let there be a plain Speculum seated at the Distance of ten Feet, the coloured Image of the Object will fall upon the Surface of the Glass, without passing through ; because behind the pellucid Glass there is an opaque Lamen or Leaf of Mercury, which reflects the Image to the Eye : in that Case the
Mind

Mind judging in its usual manner concerning the Distances of Bodies, will see the Image as if it was at the Distance of twenty Feet, with the same Sense of Space or Distance, as if the Image had passed on through the Glass to the Distance of ten Feet behind in a right Line. If you see the Image of a Tower in a Speculum a Mile distant, it will appear in the Glass as if it was a Mile behind the same. It is therefore a constant Law, that we see coloured Objects represented as if their Distance was continued in a right Line.

§. 534. But if these Rays pass out of *one Medium*^{*} into another they are incurvated at their Approach near to the latter, and then they continue on in a strait Line through the same Medium : and thus are the Rays incurvated more towards the Perpendicular, in proportion as the latter Medium or Body is more dense, and the more do they diverge or recede from the Perpendicular in proportion as the Medium or Body is more rare ; excepting that Difference which arises from a particular and latent Cause in some certain Fluids, no otherwise discoverable than by Experiments. This Incurvation of the Rays either to or from the Perpendicular, is called their Refraction.

^{*} So long as the Rays pass through an uniform pellucid Medium, they receive no Alteration in their Course, nor is there any Cause to change their Direction. They would therefore go on *ad infinitum*, in the same Line of Direction, as they came in from the radiant or reflecting Point : but when the Medium which it enters is more dense, the

the Ray is then drawn more towards the Perpendicular, than in a rarer Medium; and this more in proportion as the second Medium is more dense than the first. Thus if a Piece of Money is placed in the Bottom of a Drinking-pot, in such a Manner that the Margin of the Pot just conceals the Money; if then the Pot or Mug is filled with Water, the Money will by that means appear visible to the Eye, though held still in the same Place, and seem as if it was raised by the Water. For in this Case by pouring in the Water, the Rays diverging from the Money, are collected more together towards the Perpendicular or Point, which Geometricians easily determine, and call the Focus; but this is found from the Nature of the given Curve, in which the Ray falls; for by that means the Density of both Mediums may be known.

§. 535. But this Refraction of the Rays as to Sense, is constantly performed agreeable to the following Rule: namely, if the same Ray falls into the same transparent Medium, at different Angles of Incidence; then the Sines of the Angles of Refraction will be to each other, as the Sines of the Angles of Incidence.

§. 536. Hence therefore the Rays coming from the radiant or reflecting *Point*¹ to the pellucid *Cornea*², are there *refracted*³ towards the Perpendicular, almost in the same Manner as if they entered into *Water*⁴; and thus they go on through the aqueous Humour, by which means they are *determined*⁵ to pass thro' the Foramen of the *Pupil*⁶, so as to fall upon the Surface of the crystalline *Lens*⁷; but those
Rays

Rays which entered the Cornea so *obliquely*⁸, as to fall upon the Iris, are reflected back again out of the Eye, lest being reflected and entering the Eye, they should cause undistinct Vision: and even the other Rays which by their Obliquity fall betwixt the Uvea and *vitreous Body*⁹, upon the Surface of the ciliary Ducts or lower Part of the Uvea, are then suffocated in the black Pigment which is there seated, in the same Manner as if they had never entered; and thus no other Rays can pass through the vitreous Humour, but what have first entered through the Pupil, and fallen upon the Surface of the crystalline Lens. In the mean Time the Iris being *contracted*¹⁰ or dilated, admits more or fewer Rays, as the Object is more vivid or illuminated, and nearer to the Eye, or more languid and remote, with this Difference, that the more luminous and the nearer the Object, the smaller the Pupil, and the reverse; and thus is formed the Machine of the Eye described (§. 520), which defends the tender Retina from being injured, dried up or burnt by the Rays of Light.

¹ This Point is a lucid Spot, which is as a Center to the Rays, which are dispersed from thence into a Sphere of an infinite Diameter. When these Rays of Light fall obliquely upon an opaque Body, they are reflected back in an Angle, equal to that in which they fell upon the reflecting Body. If they fall in a right Line, they will turn again in the same direct Course; or if they make an Angle with the Surface of the reflecting Body, they

they will return from it in a like Angle. That Point of the Body upon which the Rays fell, and from whence they return, is called the reflecting Point, and has the same Properties or Affections with the radiant Point. For Example, let the Sun be the radiant Point, then the Surface of a Speculum or Mirror, upon which the Image falls is the reflecting Point. For the rest, this whole Matter seems to have been treated in the best Manner by the celebrated *Huygens*, in his ever to be esteemed Book of *Dioptrics*, as also by *Barrow*, in his *Cantabrigian Lectures*.

² The Cornea is extremely pellucid, upon the Surface of which the diverging Rays fall from the radiant or reflecting Point, as many of them as can be contained in a Cone, whose Basis is the Cornea, and Apex the radiant Body. This follows from the equable Motion, with which Light in general is dispersed by Rays from the lucid Center, every way in a Sphere.

³ But when these Rays have reached the Cornea, they begin to be strongly attracted towards the Center of the more dense Medium, by which means they converge or run towards each other.

⁴ The Cornea has near the same Density with Water, and therefore it refracts, or causes the Rays passing out of the Air to approach each other in the same Manner as if they entered Water.

⁵ The Rays of Light which pass in a right Line through the Middle of the Cornea, go on in the same right Line to the Bottom of the Eye. The other Rays converge, and though they diverge in the Air, yet after passing through the Cornea, they are drawn towards the Center, in proportion as the Cornea is more dense than the Air. But the Figure of the Cornea is spherical, or rather inclining

inclining to a Sphere, from which it deviates in some measure, being a Segment of a less Sphere than that of the Sclerotica; for the Figure of it depends upon the Humour extending the Cornea, as a flexible and elastic Plane. But this Expansion by the Humour is not perfectly equable, since the aqueous and vitreous Humours gravitate more downward than forward, almost in all Positions of the Eye; whence the Cornea becomes flatter than it ought to be. Other expert Opticians pronounce the Cornea to be of an hyperbolical Figure; but it would be very difficult for them to demonstrate that Figure which they seem to have invented in their own Imaginations: but it will be best for us to admit the Cornea to have almost the same Properties with the Sphere, and therefore to place the Focus of the Cornea behind, at the Distance of a Semidiameter behind the greatest Convexity of the Cornea. The aqueous Humour does not alter the Refraction, since its Density and Pellucidity are agreeable to that of the Cornea.

⁶ The Foramen of the Pupil is less than the Cornea, and seated behind that Membrane; and yet it receives almost the same Number of Rays with the Cornea, because they were by this last render'd converging, by which means a greater Number of Rays are admitted to the Bottom of the Eye, than if it was not provided with the Cornea, and they were to pass on converging through a less Space to their Focus at the Bottom of the Eye. Without this Refraction, but very few and only parallel Rays would pass to the Retina, while those Rays which fell upon the Iris would be reflected back again out of the Eye.

⁷ The Rays of Light which the Cornea refracts towards its Focus, are all carried to the crystalline Lens. This is a Segment of a less Sphere than
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the Cornea, as may be easily known or demonstrated by comparing the Lens with the distended Cornea in a living Person. Upon this Lens fall those Rays which were rendered converging by the Cornea, and which are here again refracted and collected into a Focus. Nor are the Rays much more converged or refracted in passing through the crystalline Lens, notwithstanding that is more dense and specifically heavier than the aqueous Humour; nor can I by any means think that the Refraction is so much increased by the Crystalline as *Huygens* believed: only the Figure of this Lens being a little more spherical, causes an Alteration in the Course of the Rays; to which we may add its small Degree of greater Density. The crystalline Lens is in general a little smaller than the Cornea; nor can the crystalline Lens by any means be formed larger than the Cornea, because the whole Margin of the Lens is spread with a very black Pigment, by which those Rays are suffocated which fall upon the lateral Parts of the Lens.

⁸ The Rays of Light which fall in a too oblique Direction upon the Surface of pellucid Bodies, are not transmitted through, but reflected back from them. Thence the Sea-water which appears black at Noon, reflects the Brightness of the Sun both at its rising and setting: but when the Sun is risen higher above the Horizon, so as to send its Rays perpendicularly, they are then transmitted into the Water, without any of them being reflected; but when the Sun is near the Horizon in a Morning or Evening, its luminous Rays falling obliquely upon the Water, are reflected with so great a Brightness to the Eyes of the Spectator, that it is not without Injury to his Sight that he can behold them. Those Rays therefore which fall too obliquely through the Cornea, are reflected from

from the crystalline Lens; and as the Angle of Reflexion is equal to the Angle of Incidence, they will fall upon the interior Part of the Uvea. If now the Uvea was pellucid or white, it would a second time reflect the Rays again, so as to make them fall upon the Retina, and disturb the distinct or true Image of the Object which is necessary to perfect Vision. Hence therefore Nature has covered the internal Surface of the Uvea with a very black Pigment, in which all the oblique Rays are absorbed, that none of them may pass to the Retina, but what go on in a right Line through, and refracted by the crystalline Lens.

⁹ The vitreous Body differs but little in Solidity from the crystalline Lens, being a small matter specifically heavier than the aqueous Humour. It is seated in the Back-part of the Eye, with the crystalline Lens in the Middle of its Fore-part, and the ciliary Ducts on the Sides; and therefore the Rays are not altered in their Course through the vitreous Body; and the less, when the ciliary Ducts being contracted, press back the vitreous Body so as to render it a little more compact or solid. They seem to produce this Action, whenever the Rays require a greater Refraction, to direct them into a certain Focus. For if the vitreous Body becomes but a little more solid, the Focus will be considerably changed.

¹⁰ Ask a Friend, or rather a fearful Child, to look with his Eyes towards a clear Light, and you will then perceive the whole Eye appear coloured either with Blue, Grey, Chestnut, &c. while the Curtain of the Pupil at the same time contracts almost to a Point. Afterwards order the same Person to look attentively at a Piece of Money placed in a Hat, in order to distinguish the same; you will then perceive the Pupil conti-

nually dilate, till it is so large as to make the whole Eye appear black, except the Tunica adnata. Nature has provided this wonderful Mechanism in the Eye, to defend the Retina from being burnt up by too great a Quantity of Light, falling suddenly into the Eye. For a Person may become suddenly blind by looking strongly at the scorching Noon-Sun in the Summer-time; which kind of Blindness is frequent among the *Chinese*, who from a religious Superstition, follow the Course of the Sun with their Eyes, from the rising to the setting of it. I myself did in a clear Night in the Winter-time, collect the Light of the Moon by a Speculum, consisting of a Segment of a Sphere; and by suddenly looking at the Focus which was received upon white Paper, in order to determine by *Fahrenheit's* Thermometer, whether there was any Heat perceptible in the Focus of the lunar Rays; I had by that means the Appearance of a white and splendid Circle before my Eyes in the Air, which continued for several Hours, insomuch that I began to be afraid of Blindness. Astronomers usually imitate Nature in this respect, by looking at the most splendid Objects through a small Aperture to temperate the Rays of Light. *Robault*, among the *French*, looking eagerly thro' a Telescope for a considerable time to observe a Battle at a great Distance, had the Use of that Eye vitiated for ever after. So great may be the Injury of suddenly admitting the luminous Rays to fall into the Eye before the Pupil is warned and contracted. 2. A second Use of this Apparatus is for it to dilate surprisingly in a dark Place, and admit the Rays in the greatest Abundance. For the Diameter of the Pupil being three times augmented, the Space admitting the Rays will be nine times larger; so that a Light nine times

times weaker, will affect the Eye equally as much as a full Light admitted through a contracted Pupil. Hence all our Pupils are dilated in the Evening, as any one may easily perceive, by advising his Friend to look at and distinguish the Colours of any Object in a dark Corner. 3. If the same Object be looked at in the Light, the Pupil will be contracted very small. But we observe that it dilates, when we look attentively at any remote Object: as, for Example, at a Clock upon a Steeple in order to determine the Hour; for the Rays entering the Eye from the Object, are in a duplicate Ratio to the Distance; so that at twice the Distance, four times a less Number arrive at the Eye, at three times the Distance, nine times fewer are the Rays, and at ten times the Distance, they are a hundred times fewer. Since therefore the Briskness or Vivacity of the Sight depends upon the Number of luminous Rays which enter the Eye, and since from a remote Object there are but very few Rays received, therefore that defect is assisted in us by a Dilatation of the Pupil, which being enlarged, admits more Rays in proportion, as fewer of them are sent to the Eye from the radiant Surface; and thus the Obscurity of remote Objects is in some measure but not totally removed. But in a near Object as in a strong Light, too great a Quantity of Rays may incommode the Eye: the same thing therefore takes place with respect to the Eye, in a weak Light, as we observed with regard to remote Objects; and in a strong Light, as we observed with respect to near Objects. In Cats the Pupil has a different Fabric. For these are capable of seeing both in the Night-time, and in the Sunshine of the Day without Injury. In this Creature there is therefore a double Curtain, by the recession or approaching of which, the ob-

long Aperture of the Pupil is increased or diminished; for they are provided with particular Muscles performing those Motions. When they look in the Sunshine, they draw these Curtains of the Pupil so close to each other, that the Aperture or Slit betwixt them is no wider than a Hair: whereas in the Night-time, the Pupil is so dilated on all Sides into a Circle, that almost the whole Cornea appears black. The same Fabric is observed in Dormice. There are other Animals again, who having the Pupil very large, and not capable of contracting in this Manner, they can therefore only see in the Night-time, as the several Sorts of Owls and Night-birds.

§. 537. Therefore the more *plain*¹ or flat is the Figure of the Cornea, the less does it refract or converge together the Rays coming to it from any lucid Point, and the more does it spread them afterwards; so that fewer Rays are conveyed through such a Cornea to the crySTALLINE Lens, and those also greatly diverging unless they proceeded from some very distant Object: but the *rounder*² the Cornea, so much more does it unite or converge the Rays coming to it from any Point, and the more of them does it collect and throw upon the crySTALLINE Lens, converging them very much together. And from hence we may understand the Reason of Short-sightedness, called Myopes or Pur-blind, and of Dim-sightedness in old People.

¹ Those who have the Cornea thus vitiated, see near Objects more confusedly, but remote Objects they

they see more distinctly ; which is a Disorder naturally following in old People, in whom the contracting Force of the Fibres overpowers the expansive Impulse of the Humours. In Infants the Eye is extremely spherical by a kind Providence of Nature, lest they should be too soon injured by the Rigidity or Inactivity of the Solids ; but by degrees they become flatter, insomuch that after fifty Years they are usually incapable of seeing near Objects. But the Reason why flat Eyes see near Objects confusedly, is, because the Office of the Cornea being to refract or converge the Rays, more powerfully as it is more convex or perfectly spherical, it terminates them into a Focus too soon, as they converge more than they ought ; for such is the Proportion in the Fabric of a healthy Eye, as to determine the Focus itself upon the Bottom of the Retina. But when the Cornea is flatter than it ought to be, the Rays do not sufficiently converge, but their Focus falls behind the Retina, as in the other Case it terminated before the Retina : so that in both these Cases the Retina does not receive the Impression of a single Pencil of Rays, but of a great many separated Rays. But when the Object is very remote, so that its Rays may be taken as parallel, flat Eyes are then capable of seeing the same more distinctly. Old People and those who cannot see near Objects distinct from such a Defect in the Shape of the Eye, are assisted by convex Glasses, the Force of which refract or collect the Rays more together, so as to produce the same Effect as if the Cornea itself was more spherical.

² Of this kind are the Eyes of Children, who are frequently short-sighted from the too great Convexity or Roundness of their Eyes ; but then such have usually their Sight better in old Age, so

that they need not the Assistance of Glasses. In this Case the Rays converge too much, and form a Focus before the Retina, too near to the Cornea; but the Rays naturally diverging again from that Focus, do not paint themselves upon one, but upon many Points of the Retina. Such Eyes therefore will not be capable of seeing distant Objects: but the greatly diverging Rays of nearer Objects will not be so easily collected into a Focus before the Retina, by the greater refracting Power of the convex Cornea.

§. 538. The crystalline Lens collects still nearer together the received Rays which were determined to it by the Pupil, and renders them converging in such a manner, that those which arise from one Point of the Object out of the Eye, are here again collected in a Point not far from the Body of the same Lens, passing through the vitreous Humour to the Retina, where they paint precisely that Point only from whence they arose in the Object. If the crystalline Humour is very *dense*¹ or round, then the Focus or Point of the collected Rays will be too near the Lens, whence the Sight will be confused; but if it is too lax or flat, the Point will be removed too far, whence also will arise confused Vision: and hence again we have another Reason why People are short and dim-sighted.

¹ The Powers of Attraction are as the Densities of attracting Bodies; and therefore a more dense or compact Lens will attract the Rays more powerfully, and cause them to converge sooner. From
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this Principle it may sometimes happen that even old Men may be short-sighted. But when the crystalline Lens is more lax than usual, it does not sufficiently collect the Rays together; and under such a State of the Lens, even young People may be troubled with the Dimness of Sight that attends old Age. But these Disorders are not remediable by the Assistance of Dioptrics, nor are they scarce to be cured by any other Means.

§. 539. From hence therefore it is evident, why the Myopes or short-sighted are assisted by a concave dioptric Lens, or by placing the Object nearer? and why the Presbytæ or old People see more distinctly with a *convex*¹ dioptric Glass, or by removing the Object to a greater Distance? Both these may be accounted for from what has been said before at §. 537, 538.

But these Defects (§. 539.) may be also remedied naturally, by bringing the crystalline Lens nearer to the Cornea, or removing it a greater Distance from thence; which Motions seem practicable two different Ways, namely, by compressing the *Globe*² of the Eye by a strong Contraction of the four Muscles at one and the same time, so as to render it more elongated; or, secondly, by a *Contraction*³ of the Fibres or ciliary Ligaments (§. 522.) so as to compress the *vitreous*⁴ Body, and thrust out the crystalline Lens. Nor does there appear to be any other Cause in the Eye capable of producing this Effect.

¹ The Perfection of the Eye consists in collecting the infinite Number of Rays which arise from any one visible Point, so as to make them unite into one Point again upon the Retina, and paint there the Image no larger than a Point, nor yet divided into more Points than one. That this may be performed in the most exquisite and perfect manner it is necessary for the aqueous Humour and crystalline Lens to have a just or exact Degree of Density, while the Length of the Eye and Figure of the Cornea are at the same time adequate. If now the Eye becomes flatter than it ought, the Rays which come to it greatly diverging from a near Object, will not concur sufficiently together to terminate in a Focus upon the Retina, where the Vision will be therefore confused. From hence every body was by this Depravity of their Sight, denied the Use of Books after the fiftieth Year of their Age, until by the modern Assistance of Glasses they were render'd capable of reading Books, the principal Delight that remains to wise old Men, without having their Letters an Inch long and broad. But now since the Invention of Spectacles, old People may read commodiously by causing the Rays, which come from several near Objects to converge more together, by which means they see them as distinctly as if they were placed at a great Distance. But on the contrary, the Myopes or Short-sighted render the Cornea as it were flatter by the Use of a concave Glass, which causes the Rays to enter the Eye in fewer Numbers, and more diverging, as if they came from a very near Object, making them unite together in a Focus at a greater Distance.

² Any Person who would see very minute Letters distinctly, ought either to remove them to or from the Point in which they can be best read.

But

But this Point is various in every Person. But to enable any one to see distinctly beyond this Point of Vision, he must make use of other Helps. For the Figure of the Eye may be changed, when we are not capable of altering the Distance of the Object; and thus may the Sight be accommodated to view very distant or near Objects. This has been elegantly demonstrated by Dr. *Pemberton* in his inaugural Thesis, where he maintains that a Sail cannot be distinguished at the Distance of two Miles upon the Sea by the oldest Person, unless the Eye is so compressed by the four right Muscles, as to render its anterior Part more convex: in the same Manner as if a flexible Vessel full of Water was to be pressed more violently in three Parts than in the Fourth, and then by adding a Pressure from any Cause, the Part less resisting would then be pressed out. Hence the Eye is tir'd or painful, when we accurately view a very distant Object; and if there is a Friend present, who endeavours to view well the same distant Object, you will perceive the Forepart of the Eye itself rise up into a greater Convexity. We are not indeed ignorant of what *Perrault* has said in Opposition to this Opinion, namely, that the Sclerotica of a Whale is almost an Inch thick; but then it becomes gradually thinner towards its anterior Part, where the Cornea is more than ten Times thinner than the Sclerotica, so that it must necessarily give way to any Pressure acting upon the Bulb of the Eye and its contained Humours.

³ This Contraction of the ciliary Ligaments is the second Cause of distinct Vision of Objects at different Distances. For the ciliary Ducts or Ligaments are incumbent both on the crystalline Lens and vitreous Body; so that when this Tunic is contracted (§. 520, 522.) it changes the Tunic of
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the vitreous Body from a right Line into an Arch ; and then the crystalline Lens is without doubt thrust forward, because a Pressure is exerted upon the Sides of the vitreous Body, while its Middle remains free. These two Causes render the Eye a moveable Telescope, capable of accommodating it self to Objects at all Distances, and of changing their focal Points. A most profound Geometrician has wrote upon this Subject, and looked upon the ciliary Tunic to be a spiral Muscle to the crystalline Lens, which he thinks it is capable of flattening, or rendering more convex ; and it is likewise thought that the Lamellæ of the Crystalline may by the same Means be pressed closer together, or removed at a greater Distance asunder. But this Author has assumed several Things which ought not to be allowed by every Body. For my own Part, I make use of no other Assurances than what are to be found in the Eye ; and I believe this Explanation to be every way sufficient to account for the Appearances.

4 Then the crystalline Lens is thrust forward, while the vitreous Body becomes more compact, so as to more accurately collect or converge the Rays, and to determine their Focus into a very small Point. And in this Manner is the Eye changed, when we accurately examine very minute Objects ; nor is any great Alteration required in order to direct the true Picture of the Object upon the Retina.

§ 540. The *Refraction* ' of Rays passing out of the Air through the Cornea, is equal to that of Rays falling out of Air into Water ; and the Refraction of them from the aqueous Humour into the crystalline Lens, is nearly
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the same with that of a Ray, passing out of Water into Glass, which is but small; and lastly, the Refraction which happens from the passing of a Ray out of the crystalline Lens into the vitreous Body, makes but little Alteration; or the vitreous Body being compressed and rendered more dense, may perhaps make the Difference little or nothing; and therefore the Necessity of the vitreous Humour seems principally to be, for retaining the crystalline Lens freely moveable, so as to be capable of accommodating itself to the Retina at different Distances; while in the mean Time the Mass of the crystalline Lens itself, retains its Figure more firmly or constantly than the vitreous Body.

This Refraction is constant in the aqueous Humour, since like Water it is incompressible, and therefore its Density remaining the same, its Refraction will not be altered. Water indeed is a little rarified by boiling, and refracts less; but when congealed into Ice, it refracts a little more: but these Alterations do not take place in the Eye of the living Animal. But in the crystalline Lens the Refraction is altered, as well as in the vitreous Body, which consisting of Sacculi may be compressed, so as to increase a little their refracting Power. But it was necessary for the vitreous Body to be softer than the Lens, that it might be capable of changing its Place.

§. 541. The whole Apparatus then occasions a distinct and vivid Collection of those Rays which come from any one *Point* ¹ of an Object,

Object, so as to make them meet in the Bottom of the Eye directly under the Pupil; and thus penetrating the Cornea, Pupil, and crystalline Lens, they *paint* ² as many distinct Points upon this Bottom of the Eye, as are conspicuous in the Object, a small *Image* ³ of which is therefore painted upon the *Retina* ⁴.

¹ The Eye cannot see more than one Object distinctly at a Time. This may indeed seem a Paradox to some, but it is matter of Fact, as any one may demonstrate to himself. For Instance, take up a Book, and you may see a whole Page at once, but endeavour to read it, and you will not find it possible to read all the Lines of the Page at once, but some will appear distinctly and others confused: nor yet can you read one Line at once, for in the same Series of Letters, some will appear languid and others more vivid. The Mind then sees but one Letter at a Time, so as to distinguish and read it accurately; and though it sees the rest, it is in a confused Manner. If you see a Grain of Sand removed to the Distance of one Foot, you will there perceive it very distinctly by looking at that alone; and yet I affirm that you cannot see the whole Grain of Sand distinctly, for every one of its Parts may be afterwards viewed distinctly or apart, when the Eye successively fixes itself upon single Points of the same Grain. But then, why does it seem to ourselves as if we saw many Things at once? This is, because the Eye with incredible Velocity is adapted to run over many Objects in the smallest Instant of Time. Nor does the Sense or Impression of Objects immediately vanish, so that the first Letter is not lost in order to attend better to the next, but the Image of the former is retained

retained in the Mind for some time, together with the new Image of the last, and applied together in so small an Instant, that they seem to arise in the Mind at once. If a Stick three Feet long, with one End of it burning, be whirled round in a Circle, at the Distance of six Feet from the Eye, it will afford the Appearance of a fiery Circle, when at the same time the Extremity of the Stick is only visible as a single Point; namely, because the first Image continues in the Eye, till it is followed by the second and third, &c. Boys make a red Spot upon the Head of a Whipping-top, and by working it round very swiftly by the Scourge, that Spot seems to be a red Ring, because the stronger Colour continues in the Eye, renewing the same Sensation in different Points of the same Circle, with incredible Swiftnefs: thus true is it, that we do not see several things distinctly at one time, but the Mind is deceived by the lasting Impression of the Image, and great Velocity of the swiftly moving Eye, by which things seem to appear present at one Instant, which follow successively after each other.

² In an Eye, which has been taken out of the Orbit, and cleared of all the Fat, let the back Part of the Sclerotica be cut off opposite to the Cornea, and instead of the Sclerotica apply a Piece of white Paper; by that means if you look on one Side, the Images of the circumjacent Bodies will appear painted upon the Paper, which is placed instead of the Retina behind the vitreous Body.

³ So long as the Rays converge together, from an infinite Number of Points in the Object, into one within the Eye, the Image will be painted like the Object; but when they fall separately, the Object will be either multiplied or the Sight confused. I saw a Man who beheld every Object

as three, in whose Cornea perhaps there might be several Planes like a multiplying Glass. But it is possible for the Rays proceeding from an infinite Number of Points, to converge together into one upon the Retina, as may be demonstrated from that Proposition of *Euclid*; namely, that the same Number of right Lines may be drawn in the least Circle, as in the largest, and the same Number of Divisions made in one as in the other.

⁴ The crystalline Lens spreads the Rays very largely round the whole Surface of the Retina. The Magnitude of the Cornea being given, with the Depth of the Eye, and Convexity of the crystalline Lens, let a right Line be drawn through the Middle of the Cornea and Pupil to the Sides of the crystalline Lens; and thus you will see what Part of the Eye is illuminated by the Lens, after the Rays have been refracted. It is almost a third Part of the Eye, the other two thirds of that Organ being blind or insensible.

§. 542. Now as the mucous or soft Pulp, namely, the Medulla of the optic Nerve, is seated *directly* ¹ in this Point, under the Pupil and crystalline Lens; this is evidently the Part which receives the Pictures of the Objects, and conveys by its Continuity the Impression of the Image to the common Sensory, so as to excite in the Mind an Idea of the thing seen.

¹ The optical or visual Axis of the Eye, determines the Point of Vision to fall upon the expanded Medulla of the optic Nerve, and therefore the Image of the visible Object falls upon the Medulla itself of the Brain. There, that is in the Medulla
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of the Brain itself, the Mind sees, and not the Eye, as *Aristotle* justly observes. But it is not the Business of a Physician to enquire what Vision is in the Mind, only he is to know what it is in the Eye; for let the Eye be sound or duly formed, and the Inhabitant will see by it, as *Paracelsus* rightly observes.

§. 543. Even this medullary Expansion of the optic Nerve, appears evidently to be the Seat of Vision from the Experiments of *Picard*¹ and *Mariot*; so far are those Experiments from opposing the same thing, as some Authors have imagined. And here the Infinite Wisdom of the Architect is to be admired and adored, for not placing the Entrance of the optic Nerve in the Axis of Vision, nor towards the external Angle of the Eye, but in a Middle Altitude, and towards the Nose.

¹ A Person who can see most distinctly, may direct his Eye in a certain manner towards the Nose, so as to see a black Spot upon it. And this happens when the Eye is so turned by the Action of the oblique Muscles, that the Center of the optic Nerve looks towards the Nose; for that Point in the Center of the Nerve is blind. Upon this is founded the celebrated Experiment of *Mariot*, and that of *Picard*. Namely, let a Person measure the Height of his Eyes upon a Wall, and there make two black Spots, at the Distance of a Span from each other, or at a Distance equal to that of the Eyes from each other; and then let the left Eye be shut, after which the right Eye will see both the Spots: when this is done, let the right Eye be directed towards the left Spot,
and

and let him recede backward by degrees, and at a certain Distance the right Paper will become invisible. This happens when the Spot is opposed so obliquely to the right Eye, that the Axis of Vision falls at the Distance of a sixth Part of the Diameter of the Eye, measuring from the Nose; for then the Object is opposite to the Artery which lies in the Middle of the optic Nerve, so that the Eye is perfectly blind to that Object. The celebrated Geometricians *Picard* and *Mariot* observing this Experiment, from thence concluded that the optic Nerve was not the Organ of Vision, and therefore substituted the Choroides for that Office instead of the Retina; for then, say they, we see nothing of the Object, when it falls directly upon the Middle of the optic Nerve. But in that Case the Image is not impressed upon the optic Nerve, but upon the Artery which runs through it; whereas the Nerve only is sensible, and not the Artery. From this Observation a Reason may be given, why the optic Nerve is rather inserted towards the Nose, than in the Middle or opposite to the Axis of the Eye, or even towards the external Angle; namely, because the Eye would then be blind to all remote Objects; whereas now only that Point is blind which falls towards the Nose, the Sight of which is less necessary, and falls upon a Part of the Object, which we never lose Sight of, so long as we enjoy the Use of both Eyes. Thus have we explained that wonderful Fabric of the Eye, the Perfection of which admits of no Improvement, and upon which the whole Science of Dioptrics is founded.

§. 544. The *Perfection* ¹ of Sight therefore depends upon such a *Figure* ², *Pellucidity* ³,
Fabric

Fabric ⁴ and *Power* ⁵ of the Solids, together with such a Density and Pellucidity of the colourless *Humours* ⁶, as may best determine or collect the greatest *Number* ⁷ of Rays coming from a visible Point of an Object, without mixing with others into one distinct Point of the Retina, placing the Focus neither too near, nor too *far from* ⁸ that nervous Expansion: and further, the Perfection of Sight consists in such a free *Mobility* ⁹ of the solid and fluid Parts of the Eye, as will be sufficient for the clear and distinct painting of Objects, though placed at different Distances; for thus the Ideas of Magnitude, Figure, Distance, Situation, Motion, Rest, Light, and Colours are best represented: and lastly, it is necessary for the Retina to have that Situation, Expansion, *Sensibility* ¹⁰ and Tendernefs, together with a due Proportion betwixt the medullary Substance, and *arterial* ¹¹, venal and *lymphatic* ¹² Vessels as will suffice to transmit the Images freely and unaltered through the well-conditioned optic Nerve, to the common Sensory.

¹ The Knowledge of this Perfection of the Eye, leads us to find out Means for assisting the several Disorders of the Sight. But the Perfection of the Eye is greatest from the eighteenth to the fiftieth Year of Age, and consists in our seeing many Objects very strongly and distinctly, without any Increase or Decrease at different Distances, so as to behold the most remote and near Objects fully and accurately (see §. 522.) From this Definition of the Perfection of Sight, there arise three

Classes of Diseases. In the first of which, the Eye is adapted to see only at one Distance, or can observe well only very remote, or else very near Objects. 2. If the Eye does not see briskly, it is called a Dulness or Imperfection, the Object then seeming as if it was observed through a Cloud in the Middle of the Day; and this Disorder is frequent to old People, whose Eyes begin to be opaque. 3. Lastly, the Vision may be undistinct. The Distinctness of Vision arises from an infinite Number of Rays converging together into one Point, which falls exactly upon that Part, in which the optic Nerve covers the Eye. When the Focus or Point of converging Rays falls behind the Retina, the Rays then come to it separated, or before they are collected together, and therefore paint not one but many Points upon it. When the Rays converge more than they ought, the Focus falls betwixt the Retina and the crystalline Lens; and then from that Focus which they make in the vitreous Body, they diverge again and paint many Points, when they ought to paint but one. From both the preceding Defects arise a Confusion of the Images in the Eye, whether they are several or single. These contrary Defects of the Sight are easily demonstrated from the Particulars required in the most perfect Sight.

² The Convexity of the Eye determines the Rays in a Focus upon the Retina, so that they do not converge before or behind the same. The Eye ought also to be perfectly spherical, so as to be susceptible of the greatest Number of Rays.

³ The Pellucidity of the Eye ought to be as perfect as possible; for so soon as there is the least Opacity, the Eye is continually deceived, though it should be free from all other Defects. Thus the Pupil ought to be very black; and in general
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the Eye is better, as the Pupil appears blacker. Nothing ought to be seen in the Pupil unless the reflected Image, as if coming from a Glass; for if there is the Appearance of the least Whiteness perceptible in the Pupil, the Sight is always dull in proportion.

⁴ The least Alteration in the Fabric of the solid Parts excites Diseases of the Eye. I examined the Cornea in the Eye of an Ox, by pressing upon the Back-part, to distend the Cornea outward as much as possible, in the same manner as it is observed in the living Animal; and then with a very small Needle and a Microscope, I punctured the exterior Surface of the Cornea slightly, by which means an elastic Lamella or Pellicle of the Cornea contracted and enlarged the Opening; and then again I repeated the same Puncture through the next entire Pellicle, which contracted and made a new Opening as before: and in this manner a hundred Strata may be distinguished in the Cornea, by puncturing as many times; whence the Cornea appears to be made up of an infinite Number of concentric Strata. But it is remarkable, that at each Puncture a small Quantity of Water was discharged; and therefore the Cornea seems to be also composed of very fine lymphatic Vessels, many of which are interwove into a Stratum, several of which Strata make up the whole Membrane of the Cornea. Now if any one of these Strata is vitiated or diseased, the Perfection of the Sight will be impaired; but if a small Fissure or Wound be made in the Surface of the Cornea, the divided Lips receding, would constitute two different Planes or Surfaces, which would continually occasion a Duplicity of Sight.

⁵ Namely, their Power of Elasticity, which is in proportion to the Extension that they suffer

from the Humours. Whenever the Equilibrium is altered betwixt the Solids and Fluids of the Eye, that Organ is always more or less vitiated or diseased. When the Power of the Solids prevails, the Eye becomes flatter, as in old People; but when the Humours too much extend the weakened Solids, the Eye becomes short-sighted, or even at length may be so protuberant and extended, as to acquire the Denomination of *Oculus elephanticus*:

⁶ These Humours are, 1. The pellucid Lymph contained in the small Vessels of the Cornea, continually moving in the Course of the Circulation. 2. The aqueous Humour. 3. The Humour which circulates through the parallel Vessels of the crystalline Lens. 4. The Humour contained in the very small Vesicles of the vitreous Body. In all these Humours is necessary a perfect Degree of Pellucidity with a certain Density. When they are less dense, they cause the Focus of the Rays to fall at a greater Distance from the crystalline Lens, even behind the Retina; but when they are more dense, the Focus then terminates too near the Lens, and even before the Retina. But it is to be observed, that these Humours are capable of being condensed or rarefied, since they are not like mere Water, but in some Degree compressible. Lastly, When these Humours of our Eye are coloured, they then represent not the true Colour of the visible Object, but that of the Humour itself to the Mind: thus when the Eyes are yellow, as in a Jaundice, all the Objects seem to be yellow.

⁷ The more numerous the Rays which are collected together into a Point, the more vivid is the Sight or Impression of the Object; and the smaller the Point in which they converge together, so much more distinct is the Sight. If the Focus of
Rays

Rays fell one thousandth Part of an Inch before the Retina, the Image would not be painted in a single Point of the Retina, but in many, and the Vision would be confused.

⁸ The Image of a remote Object appears distinct, when the Rays come to the Eye in so small an Angle, that they may be taken for parallel. But in that Case the vivid Strength of Vision is wanting, because the Rays are sent into the Eye in a small Number. Thus an old Man will be capable of seeing distinctly at the Distance of a whole Mile, but then he will not see with any great Strength; on the other hand, when the Eye can only see near Objects, the Sight is then less perfect (see §. 530); for it is better to see remote Objects well, than to be obliged to view them at the Distance of an Inch, in order to see them distinctly.

⁹ So moveable, that in an Instant of Time the vitreous Body ought to be capable of changing its Solidity, and the crystalline Lens its Situation. But when the Eye itself is perfectly moveable, it then receives an infinitely greater Force of the Rays, while it moves through one fourth Part of a Circle; since this Arch is in the Center of an infinite Number of larger Arches, from whence all the Rays are received.

¹⁰ Namely, Sensibility or Sharpness of perceiving. The Retina cannot be affected by Objects, but in proportion to its own natural Sensibility. When I look at the full Moon in a clear Night, my Eye may be so affected that I can retain the Image as if it were present, by turning round with my Back towards it; but when the Image of the full Moon is collected by a concave Speculum, and thrown upon white Paper in a single Point, in that case the Impression of a lumi-

nous Spot will remain for several Hours as if it were painted in the Eye ; and by this means a Man may be quite blinded, though there is not any Heat produced in the Focus, capable of being distinguished by the most sensible Thermometer, even that invented by *Drebel*, which arises even by a Blast of one's Breath. Hence we infer, that the Retina of a healthy Person ought to be so sensible, and capable of Irritation, as to be affected by the least Cause or corporeal Action. Upon this natural Sensibility of the Retina, the Sharpness of Vision in a great measure depends ; and this Sensibility being lost in old Age, the Eye itself is no more affected by the Sun than the Skin, namely, it continues only sensible of Heat.

¹¹ We said before that the optic Nerve in its Center is not nervous, being perforated with an empty Aperture, through which a considerable sanguiferous Artery passes in the Middle of the Cylinder of the Nerve, expanding itself together with the Retina ; upon which Artery the Image of the Object falling, is not perceived by the Mind under any other Form than that of a black Point. Now when these Blood-vessels in the Bottom of the Eye are so distended as to compress the Medulla of the optic Nerve there also expanded, the Retina itself will be likewise insensible. This Opacity or Insensibility in any Part of the Retina, is not ascribed to the Eye by the Mind ; but when the Person looks in a serene Air, he sees at a Distance as it were dark Particles dancing in the Air, which are nothing more than insensible Points of the Retina, whether that Insensibility arises from a Palsy, or from some Body placed in the Bottom of the Eye before the Retina.

¹² *Ridley* opened the Eye of an Animal lately strangled, by dividing its anterior Membranes, and

and he observed that in the Retina and optic Nerve there were distributed lymphatic Vessels, which did not intercept the Rays of Light, since they were extremely pellucid. But if the same Vessels from any Cause should be rendered less pellucid, then the Sight would be lost in those Points of the Retina, and the Mind will perceive as it were Bubbles of Water, like what People frequently see in the Clouds, when illuminated by the Noon-sun; namely, the Appearance of pellucid and dancing Globules. There is no Danger from the Appearance of these Corpuscles, as I have experienced in myself.

§. 545. The visual Rays do *not*¹ therefore *flow out*² of our Eyes, so as to be reflected again into them from Objects, as the Stoics have asserted. Nor do we see by any visible Species flowing out of the Object into us, as *Pythagoras* and his Followers have pronounced; nor yet do we see Objects by Effluvia which they emit to the Eye becoming visible by embracing each other, and then returning again, according to the strange Reasonings of the *Platonists*; nor, lastly, do we see by any material Eflux of corporeal Images, as *Epicurus*³ judged. But Vision is performed by that *Mechanism*⁴ which has been explained before, and the understanding of which has been much expedited by an accurate Description of the internal Organ of the Eye, by the celebrated *Raw* communicated in an Epistle to me.

¹ Vision is the Perception of a most subtle Body, and belongs in a manner as well to Spirits as to

Bodies. Specula reflect the Images of Bodies so accurately, that there is no living Creature who has not been used to them, but what would believe he actually saw the Person or thing itself, whose Image only is painted in the Speculum. Thus we see Dogs placed before a Looking-glass, move their Head and Eyes variously, in order to discern whether that which they see is a real Dog. This we know not what thing which so much resembles the Body from whence it is derived, has hardly any Extension, and yet it seems equally extended with the Body itself.

² If we saw by Rays flowing out of the Eyes, we should not then stand in need of Light; but certain we are that without Light we cannot see. I am not indeed ignorant that there are some Instances which are alledged in favour of the contrary Opinion: as *Tiberius*, who rising up suddenly in the middle of the Night, is said to have been capable of distinguishing all Objects; and in short, I believe that this Accident is not unfrequent, but that many Men may for a Moment clearly perceive with their Eyes when they open them in the Middle of the Night. But neither does this constantly happen to the same Person, nor is it of any Duration, the short Light being instantly followed in the smallest Moment of Time with a profound Darknes; nor does this proceed from Rays sent out from the Eye. In short the whole Affair is as follows: The Eye may become so tender, that what is no Light to others, may yet be sufficient to illuminate a tender Eye; for, properly speaking, there is no such thing as Darknes throughout the whole World; but we call that Darknes, which is a weaker Light; insomuch that Places said to be dark to us, are yet by other Animals taken for clear Lights, and, on the other hand,
our

our Light is again taken for Darknefs by those Animals. Thus a Man is capable of seeing in the Day-time, but at that Time he cannot be seen by a Dormouse; on the other Hand, we are blind in the Night, at which Time the Dormouse sees, searches for its Prey, and observes every thing very accurately. Thus also a great many Flies, especially those which have many Eyes, with half the Sorts of Butterflies and other Animals, do not see many Things well but in the Night. A memorable Instance of this Nature happened in *England*, which was cited before (§. 490), Of a Man who being thrown into Goal and deprived absolutely of all Light, both from the Sun, Moon, and Heavens, he could not see any thing for a considerable Time; but after a While he began to perceive a faint Twilight, after the Pupil had relaxed itself, and in process of Time, his Eye became so tender, that he could both see Objects and read Letters in the most profound Darknefs. Nor is there any thing very surprising in all this; for there is hardly a Physician who has not observed, that upon coming out of a strong Light of the Sun in the Summer-time, to a Patient lying ill of an acute Disease in a dark Chamber, he has not been capable of seeing for the Space of half a Quarter of an Hour, during which Time becoming more accustomed to the Darknefs, he has distinguished the Objects as if it were by a Light gradually more and more increasng. Nameiy, the strong Light had so affected the Eye, as to render it insensible of a weaker Light; when the same Eye will be able to see in the weakest Light after it has been destitute of one stronger. But to return to the Matter concerning which we were speaking; it is by no means reasonable to suppose Rays flowing out of our Eyes, which meeting with Objects are reflected back
again

again to the same, so as to bring with them the true Images, and as it were the Shells of the Bodies to the Bottom of the Eye; or else that Rays coming out of the Eyes, unite with Rays coming from the Objects, and so return together to the Eye; for all these Opinions are easily refuted, since a good Eye cannot perceive any Object without the Assistance of Light.

³ This false Opinion is not justly ascribed to *Democrates*; namely, that visible Images or Pictures wander about every way from Bodies, and are received by the opposite Eye. For this Notion is refuted by the former Argument, that upon removing Light, Vision is destroyed. These Images are the Spectra described by *Virgil*:

*Et ni docta comes, tenues sine corpore vitas,
Admoneat, volitare cava sub imagine formæ,
Irruat & frustra ferro diverberet umbras.*

⁴ Which Mechanism is as concise as possible, namely, a Collection of the Rays reflected and dispersed from the radiant or reflecting Point to the Eye.—What has been hitherto said concerning the Eye, may be safely adhered to, and supported by solid Experiments. But as *Aristotle* formerly pronounced very justly, it is the Mind which sees and the Mind which hears; whereas the Object itself is only a characteristic Mark, which excites an Impression in the sensitive Faculty of the Mind. It may be added, that Vision does not belong to Bodies, but depends on the Faculty of the Mind itself, which is capable of representing to itself Images, without the Assistance of Bodies, both when we are sleeping and waking. Even Sir *Isaac Newton* ingenuously confesses, that all which has been taught by optical Demonstration, produce

no more than a certain Change in the optic Nerve; and therefore we do not see Images by their Impressions on the optic Nerve any otherwise, than as if a Press or other Body was represented by Lines drawn with Ink upon Paper; the Lines themselves having no Relation to the Press or Body which they represent. For the Focus of Rays meeting together upon the Retina, produces nothing but a true Kind of Touch or Feeling; and yet from that Focus arises the Idea of red or other Colours. It therefore does not follow, that the Eye is affected or tinged with a red Colour, when that Idea is excited in the Mind; but the Mind has a Faculty of framing particular Thoughts or Ideas, when it is moved in a certain Manner or by certain Bodies; nor will that Colour ever arise, unless the corporeal Organ is moved in the same Manner, by the Body or Object, by Disorder or by the Mind itself. And this may be taken as a certain and infallible Law; for the same Object will constantly excite the same red Colour in the healthy Eye of every Person throughout the whole World. But our Ignorance of the Manner in which these Ideas are excited in the Mind, ought not to give us any Uneasiness; for the Business of the Physician extends no farther than to keep the Eye sound and duly disposed, that the Rays may meet together in a just Manner upon the Retina.

§. 546. From what has been said, we may be able to give a Reason why Objects appear most clearly when placed at the *least* Distance that the Eye will bear, so as to see them *distinct*? and why when the Object is removed at a greater Distance, it is seen distinctly but

but not so strongly or evidently, producing a more languid Effect upon the Eye? why Objects appear *confused* when placed too near the Eye? what is required towards a distinct, and what towards a strong or vivid Sight of Objects, &c.? All which may be easily solved from what has been before advanced.

In every Person there is a determinate Distance, at which Bodies are beheld by them most distinct, or as plain as they are capable of appearing. A Person whose Eyes are distinct will plainly see and know another Person at the Distance of two Feet, and also at the Distance of twenty Feet; but what is seen at a greater Distance appears weaker, and that which is seen at a nearer Distance appears confused. For Instance, I see a white Sail at the Distance of a Mile distinct enough, but not vivid or strongly; but as the Ship approaches nearer, I perceive the Sail more apparently or clearly as it comes nearer. But when that Sail comes within the Distance of twelve Inches I then see the Threads, which being wove together make up the Sail, and also the small Filaments or Fibres of the Flax which are twisted together into the Threads. In effect, we see best or most clearly, when the Object is placed at such a Distance, as may enable it to send the greatest Number possible of parallel Rays to the Eye, so as to make them converge upon the Retina; and therefore Vision is most vivid when the Eye receives the greatest Number of Rays, and the most distinct when they come parallel, and terminate as before upon the Retina, supposing the Eye itself to be as perfect as possible.

² We then see distinctly because the Rays are almost parallel, only they are but few in Number; by the former the Vision is rendered distinct, but by the latter more faint. But the Number of Rays from an Object diminish in proportion to the Square of their Distance.

³ When a Needle is applied as near as possible to the Cornea, it cannot be seen, because the Rays reflected from the Needle, diverge so much that they terminate in a Focus behind the Retina; and therefore we see many Points instead of one.



Of the HEARING. ¹

§. 547. **S**OUND ² is a tremulous Motion of the common *Air* ³, arising from its *reciprocal Vibrations* ⁴ or *Tremors* ⁵ and Elasticity, when struck or agitated by a *sonorous* ⁶ Body. It is propagated from the sonorous *Center* ⁷ in *right Lines* ⁸, towards the Circumference of a Sphere, as far as it is capable of extending, being nearly subject to the same Laws in its Progress and *Reflexion* ⁹, which we observed in the Rays of Light; (§. 533.) only it is propagated more slowly and *successively* ¹⁰, namely, passing over the Distance of 968 *English Feet*, within the Space of a Second of Time: a greater or *less* ¹¹ Sound moving equally, and without being accelerated or retarded by moving with or against the *Wind* ¹², though in the latter Case, the
Sound

Sound does not extend to so great a Distance; in the mean Time the Sound *impresses* ¹³ its Tremors against elastic Bodies which oppose it, and these elastic Bodies reflect the Tremors again with very little Alteration. Hearing then is the Perception of such a Sound excited in the Mind, by means of that whole Organ which we call the Ear, as well internal as external.

¹ Hearing is that Idea or Perception of Sound, which is excited in the Mind by the several Parts or Organs belonging to the Ear; and thus true Hearing is distinguishable from the Idea of Sound, which arises in the Mind from an internal Cause.

² Sound is every thing capable of being heard, which exists without us, in a tremulous Motion of the Air agitated into Waves. But with regard to ourselves, it is a Mode of thinking or perceiving Ideas in the Mind, which every one is sensible of; and no one can explain.

³ That the Air is the Instrument or Medium of Sound is evident, since without it no Sound can be heard. That the Air is the Medium which conveys Sounds, may appear among other Experiments from the following; namely, because the Sound of a Bell which I now hear being close to it, will in a Second of Time be heard by another Person at the Distance of a thousand Feet from the same Bell. But Water is not the true and adequate Medium of Sound, although Fishes are capable of hearing by it; for the tremulous Motion of the Air is continued from thence confusedly through the Water, but that Communication will be cut off if all the Air is extracted and excluded.

4 Sound being once formed continually loses itself, and is spread to other Parts where it may be heard; nor is it the same Sound that continues to be heard, but others which arise after the first. We are much deceived if we judge Sound to be one continued Motion of the Air. For Example, let there be a large pendulous Bell, namely, a hollow copper Body approaching the Shape of a Cone; and let it be struck gently in the Rim, a Sound will arise which will continue for some time, and seem constant, provided no Alteration is made in the Bell. But if the Hand is applied at that Instant when the Sound arises, so as to stop the Tremors of the Metal, the Sound will then perish as to ourselves, so as to be no longer audible; but a Person who is 968 *English* Feet distant from the Bell, when it was first struck, will hear the same Sound exactly after the Space of a Second of Time; and then after another 3600th Part of an Hour, the same Sound will be heard by a Person who is almost near 2000 Feet distant. Therefore the first Sound which you suppressed in its Origin by the Hand, was not durable or permanent for any time, but it is lost the Moment after it is perceived by the Ear, and in the second Minute of time another Sound succeeds the former and affects the Ear, and so a third in a continued Succession. Sound therefore is continually destroyed but maintained and renewed by other Sounds from the trembling Bell; but if you suppress the Tremor of the Bell, then the whole Tone or Sound is at once destroyed. Therefore a single Vibration of a Chord is not audible; but if the sonorous trembling Body which is struck, causes the Air to recede and return alternately to a certain Number of times in a given Space, then that Number of Impulsions or vibrating Motions of the Air, which are made in a given

given time by the sonorous Body are called Sound. This Doctrine has been elegantly treated by Monsr. *Sauveur*, *Hist. del' Acad. ann. 1700. p. 172.* He made use of one of the largest Church-organs, in which the Tones are very distinct, and may be continued to any time with Pleasure; which cannot so well be done by any other musical Instrument. The largest Pipe of all in the Organ makes the whole Church tremble, when it yields the due Tone; but if the same Pipe was perfectly cylindrical, and of the same Diameter on all Sides, it would not yield any Tone. But if the Air which is blown in, is obliged to pass through a narrow Aperture, then a Tone or Sound arises; whence it follows, that Sound is not a bare blowing thro' of the Air, but a Collision or beating back of the same in an undulatory Motion. If these Undulations of the Air are too slow, and not repeated in a sufficient Number in a given time, it will not be perceived by our Ears, even though it may perhaps be audible to other Animals. If the Artist makes the Pipe too small, it yields an intolerable Stridor or Squeaking; and betwixt this disagreeable Stridor and too great a Tone, which is not audible, is the Limits of audible and true Tones; which arise from a just Number of Undulations in the Air in a given time, being neither too frequent nor too slow in their Succession.

⁵ A tremulous or reciprocal Vibration of the Air. But the Vibration is said to be reciprocal, when it is impelled one Moment from A towards B, and the next Moment returns again from B towards A: for a continued or equable Motion of the Air, however strong, never produces Sound. The most swift and strong Wind will yield no Sound of itself; and if you stand in a level Plain, you will not perceive any Sound, except what arises

ses from the Collision of it against the Surface of the Earth, and against your own Cloaths. And in the most violent Storm of Wind upon the Sea, there is no other Sound to be heard, but that arising from the Conflict and Clashing of the Waves. The greatest Force of the Wind blowing upon a most high Tower, affords no other Sound than that which proceeds from the Collision of the Air against the Walls, which is indeed a Sound terrible enough, arising from the Stones and not from the Air alone. These reciprocal Motions of the Air, which we call Tremors, produce Sound, when five or six hundred of them succeed each other within the Space of a Second; whereas if fewer Tremors succeed each other in that Space of time, no Sound follows. If a musical Chord which sounds the lowest Note of all the Base, be so loosely stretched, that after touching it one may count the Vibrations, it will never produce any Sound. Even if it be stretched a little more powerfully, it will not properly afford a Sound, so long as the alternate Vibrations of it can be enumerated. But when it has been so far stretched as to vibrate several hundred times in the Space of a Second, it will then by striking yield a grave Tone, which will by Degrees become more acute, as it is more powerfully stretched; insomuch that when the tense Chord is near upon breaking, it yields a most acute or shrill Tone. From these Considerations it follows, that Sound is a tremulous Motion of the Air, excited into such quick Vibrations, as to go and return so many times in the Space of a Second, as are reckoned in the Memoirs of the Royal Academy at *Paris*, ann. 1700. p. 172. If there are more than the largest Number of Vibrations there limited in the Space of a Second, namely, 6400, it will not produce

the Idea of Sound in us ; if there are fewer Vibrations in the same Space, namely, than $12\frac{1}{2}$ in a Second, we shall not then be capable of perceiving any Sound, although there may be other Animals to which such a Sound may be audible enough.

Bells are usually cast of the most elastic of all Metals ; for soft Mettals, such as Lead, do not yield any Sound. A Bell formed of such elastic Metal may be divided in the Imagination into Circles or Sections, which while at rest, are equally distant from the Center ; but when any Impulse, though small, presses more upon one Point of the Periphera than upon another, the Figure of the Circles which compose the Bell will be changed into an Ellipsis, as is apparent to the Eye, and as may be demonstrated by tying a Thread round the Bell. But so soon as the Stroke is removed from the Bell, it not only continually returns into a Circle, but its Sides recede beyond the Circle, so as to form an Ellipsis greater than a Circle ; and therefore the whole Bell has a Body, all the Sections of which are Circles continually changing their Figure into an Ellipsis, and of returning again into that of a Circle. By this Recession and returning of the Sides of the Bell, the ambient Air is consequently obliged in like manner to pass to and from the same ; so that if the Bell be left to itself for a few Seconds of Time after it has been struck, it continues to send forth a Tone by the continual Tremor of its Sides agitating the Air ; which Tone would not be audible if the Tremor was suppressed by applying the Hand.

⁶ The sonorous Body is that which so changes the Air, as to produce Sound. For the Sound is not in the Bell which we say rings, but 'in the Air which the Bell itself agitates by its alternate tremulous Motion of contracting and dilating, by which
you

you may perceive small Grains of Sand to be struck off; as well as the Particles of the Air by the tremulous Motion of the Bell, which being composed of elastic Metal; is changed from a Circle to an Ellipsis by the Stroke, which may be demonstrated even to the Eye itself, and by tying round a Thread. But then this Ellipsis does not continue, because the Elasticity of the Metal restores it to its former Circle; after which it returns again to the Ellipsis, and so to the Circle again alternately; so as to compress the contiguous Air, and cause it to flow from and return back again to its Surface. But if the Hand is suddenly applied or pressed upon the Bell after it has been struck with a Hammer, these alternate Incurfions and Excursions of its Sides will be suppressed so as to destroy the Sound, which would otherwise have continued for three Seconds, if the Hand had been kept off from it.

⁷ From which Center the Sound is diffused or propagated as from the Center of a Circle by equal Radii, at the same time towards every Point of a Sphere. By the Propagation of a Sound we mean that when the same Sound which was heard in the Place A, ceases to be any longer heard there, passing on to the Place B, where it becomes audible; &c.

⁸ Let us suppose a Circle described, of a Mile diameter, in the Center of which is the Bell; and let us suppose the whole Periphera, or Circumference of the Circle, beset with the Ears of healthy People; in that Case every Person will certainly perceive the Sound of the Bell equally distinct, and exactly at the same time. But now let us suppose a Wall erected against one Side of the Bell, the Sound will be thereby repelled; and at some Distance from the first Wall, let another be

erected higher than the former : in that Case the Sound will not be heard in the former Place, but only in that Part to which it is determined by the Reflexion of the Wall. These Facts are easily proved by Experiments, namely, that Sound is propagated in right Lines every way from the sonorous Point or Center, in the same Manner as Light which is emitted in Rays from a luminous Body.

9 When the Preacher speaks in the Pulpit, the Audience who attend to the Sermon, do not hear the Voice of the Preacher simple or uncompound-ed ; but they hear the Voice after it has suffered an infinite Number of Reflexions from the Roof, Pavement, Walls, and every other hard Body in the Church : and from hence arises an infinite Number of Echoes, all which are not distinguished from the first original Sound. Hence it is that an Oration in a Church which is walled, is more distinctly perceived ; whereas the same would be very weak and hardly audible, if it was delivered to the People in an open Field. For an Echo by reason of the continual Succession of Sound, will return the same most distinctly, when the Wall is five hundred Feet distant from the Mouth of the Person who is speaking ; so that the whole Interval of the Passage of the original and reflexed Voice, may answer to a Second of a Minute : but if the Wall stands at half the forementioned Distance it will indeed repeat the Sound, but then the reflexed Sound will continually follow the Original ; and if the reflecting Obstacle is still nearer to the Mouth of the Speaker, in that Case the Echo will not be perceived, but mixing itself together with the Voice of the Person speaking, will render the same stronger. And therefore the Voice of a Preacher will be obscure and weak if alone,

alone, but strong when accompanied with an infinite Number of reflected Voices : and in the same manner when a musical Chord is struck in the open Air, it affords little or no Sound ; but if the same Chord is suspended in the middle of a hollow Tortoise-shell, it will afford a strong Sound. In searching after Plants in stormy Weather, among the sandy Mountains of *Holland*, I have heard the roaring of the Sea reflected from the Mountains ; but upon going down to the Vale, it gave me not a little Surprise to find myself encompassed on all Sides with a most profound Silence. When I ascended again to the next Hill, the former Noise was again audible, so long as the roaring of the Sea reflected by the Mountains could reach the Ears of a Person standing upon an Eminence or high Place ; but so soon as one is arrived to a Part of the Vale enclosed on all Sides by the Hills, so that the adjacent Sound cannot be reflected from them to the Ears, in that Case the roaring of the adjacent Sea becomes not at all perceptible.

¹⁰ The Rays of Light are propagated or spread with so great a Velocity, that their Succession may be esteemed as nothing with respect to Time ; though the Velocity of it is estimated by the celebrated *Roemure*. But Sound moves with a much less Velocity ; for it is found by Experiment that Sound runs over near a thousand *English* Feet in a Second of Time, and not being accelerated in its Course it passes through ten thousand Feet in the sixth Part of a Minute, supposing the Air to be calm in the Night-time, while the Experiment is performed by three Persons in a Plain, one of which being armed with a Gun, and the other standing with a Pendulum, while the third being a thousand Feet distant carefully attends to the Light and to the Sound of the Gun. So soon as

the Brightness of the Gunpowder is perceived, a second and a third Vibration of the Pendulum will pass before the Sound begins to be heard, which will be in the third Vibration of the Pendulum. It is found by comparing the Numbers of both Observers, that the Light was perceived by both at the same Instant of Time, but that the Noise or Sound came three Seconds of a Minute afterwards. This Celerity of the Sound is sufficient for the Security of human Life; for all Sounds which require our Attention come from adjacent Bodies, and the Succession of Time is so small as to be scarce perceptible, when the Distance is less than a thousand Feet. But if we perceive more Sounds and from more distant Parts, they are confused by the Multitude and Reflexion of them. But Light comes from a Distance almost infinite, and if that was to take up so much Time in its Passage, we should not be capable of making any Observations in the Heavens. See N^o. 4.

“ Several Experiments were made with regard to this by the Grand Duke of *Tuscany*. He chose out one of the most plain Parts of his Country, and disposed Observers at known Distances, who discharged Guns loaded with different Quantities of Powder. Others were placed also with Pendulums, the Vibrations of which they numbered betwixt the first Appearance of the Light and the Sound following; by which means they found that the Report of a Gun charged with a great Quantity of Powder extended itself in the same Time to a great Distance, (as for Example, ten thousand Feet) with the Report of a Gun charged with a small Quantity of the same Powder; so that there arose no Difference in the Velocity of the Sound from the Strength of the Report: nor did the Pendulum vibrate oftner betwixt the Flash
and

and Report of a Hand-gun, than betwixt the Light and Noise of a Cannon carrying a Ball of thirty-six Pounds. It is therefore evident that a large and a small Sound are propagated with equal Celerity; and therefore it is not in the Power of Man to increase the Velocity of Sound. In the same manner a Stone flung into stagnant Water excites it into circular Waves, which move with the same Celerity whether the Stone was thrown with a small or great Force. These Waves arise because the Stone depresses the Surface of the Water upon which it strikes, by which means the adjacent Water is raised above the Surface of the rest, in proportion to the Depressure made by the Stone; but the next Moment the Wave of Water which rose above the Horizon descends and is succeeded by another circular Wave, &c.

¹² If a Person discharges a Gun in the middle of the Night upon a Plain; and if from that Person another is disposed at the Distance of a thousand Feet with a Pendulum towards the South, when the North Wind blows, and another Person is likewise placed with a Pendulum at the same Distance towards the North, in such a manner that the three Observators are placed in the same Line of Direction with the Wind: In that Case by counting the Vibrations of the Pendulum betwixt the Flash and the Report, the same Number of Vibrations will pass betwixt the hearing of the Sound, as well with the Person who is placed with the Wind, as with the other Person who is opposite to the Wind. Whence it appears that Sound is not accelerated or retarded by the Wind. The same Success has been observed from the like Experiments repeated twenty times, and even at

greater Distances, as, for Instance, at the Distance of three *Italian* Miles ; insomuch that the Sound could never be observed accelerated one Vibration of the Pendulum by passing with the strongest Wind, nor yet retarded one single Vibration by the Opposition of the Wind. That Sound should be thus disposed to spread itself equally was necessary to the Advantage of human Life. Nor is it at all difficult to explain this seeming Paradox. *Mariot* has calculated the greatest Velocity with which a Wind seems to run, and found it to be slower than is commonly thought, even at a time when it was strong enough to blow down Houses. In the same manner a Lad can easily keep Pace with the Waves of Water moved with a great Impetus. The Wind therefore having so slow a Motion, cannot much alter the Course of the more swift Sound in so small a Distance as to be audible to our Ears : but for greater Distances the Experiment cannot be made, because the Incurvation or globular Figure of the Earth will not admit the Observators to be placed at greater Distances in a right Line. But by these Experiments it is found, that the Power or Strength of a Sound is diminished by an opposite Wind ; whereas those who hear a Sound brought with the Wind, do not hear the same sooner though they hear it stronger than those who are placed in an opposite Direction to the Wind, who hear it weaker.

¹³ The undulatory Motion of the Air communicates its Tremors to elastic Bodies, which Tremors become audible when those elastic Bodies are sonorous. If the Undulations of the Air make any Quantity of Sound which is one Octave more grave than the Tone, which would arise from the same Sound that might have followed from the sonorous Body, if it was struck without a Medium ;

in that Case the Tremors of the Air will excite Tremors in that Body, even though they do not come into contact with the same. For Example, take a musical Chord of two Feet in Length, and take another Chord of a Foot long, but of the same Size and Make, and stretched by the same Weight to an equal Degree of Tension; and in that Case the Tone of the longer Chord may be termed an Octave lower than the shorter Chord, which may be said to be one Octave higher, as the other may be said to be lower. If now the longer of these Chords is struck, the shorter one will sound even though no Alteration be made in it, and will yield a Tone one Octave higher than it naturally yields; which may be distinctly perceived by the Ear, by suddenly stopping the Tone of the longer two Foot Chord, while that of the one Foot continues to sound. Again, let there be another Chord of half a Foot in Length, and stretched as before; the whole Length of it will sound and tremble, if either the two Foot or single Foot Chord is struck; and if the Chord of two Foot long is struck, both that of the one Foot and of the half Foot will tremble and sound. And in general every Chord whose Tone is one Octave, a fifth or a third greater or less in Gravity, that Chord will cause a Tremor in similar Chords which sound an eighth, a fifth, or a third greater or less but more acute. From hence we infer that a simple and pure Sound is never heard; for there is no Place which does not reflect Sound, which wherever produced, is accompanied with a Tremor of all Bodies which yield a Tone above an Octave, fifth or third greater or less, and of their Octaves *ad infinitum*; all which secondary Sounds are confounded or mixed into one, so as not to be separable or distinguishable by our Ears.

In the same Manner in one Tone or Note upon musical Instruments, there are contained an infinite Number of others; namely, all the Octaves, fifths, and greater or lesser thirds with all their Octaves which tremble together with the Chord or other Body which yielded the first original Tone. Even if a Person was to mount upon a flying Horse, like *Bellerophontes* above the Cities and highest Mountains, in order to discern what a simple Tone or Sound is in itself; even then he would be deceived, for the accessory Sounds of the Horse and his Rider would mix with and be reflected together with the simple Sound.—This Sound composed of an infinite Number of others, so as to be hardly explicable by any mechanical Laws, is the Object of hearing. I have endeavoured with infinite Labour to ascertain universal phonergic Laws, but after being involved for the Space of two Years, the Difficulty attending the Subject hardly allowed me to make any Progress.

§. 548. Hence therefore we learn that the *smooth* ¹ Membrane of the external Ear, anointed in its external Cavity with a *Lini-ment* ², but almost without any *Fat* ³, is firmly stretched upon a thin elastic and tremulous *Cartilage* ⁴, which adheres by a cartilaginous Basis to the Os temporale; so that being thus in a State of Tension, it receives and strongly reflects together the sonorous Rays without suffocating or *changing* ⁵ them.

¹ This smooth Membrane is neither loose nor fluctuating, but tense and polished without any Wrinkles; and by that Means is well adapted to receive and reflect together the sonorous Rays, which

which are not at all lost or smothered by the small Hairs growing in this Membrane ; for Hairs are the most sonorous of any Bodies : and thus *Kircher* has observed, that the Leaves of the Trees in a Wood reflect an agreeable Echo which cannot be perceived in the Winter, when the Leaves of the Trees are fallen off.

² This Liniment is formed in Cryptæ or Cells, which transude an oily Cerate to preserve the Membranes of the Ear in a due State of Tension ; which Membranes would be destroyed if they were to grow dry, in the same Manner as musical Chords perish if they are not defended with Oil or Resin. That this Oil is perpetually separated or prepared in this Membrane is evident, since if the Ear be rubbed a hundred Times in an Hour with a Piece of black Velvet, there will be continually new Sordes wiped off, and visible to the naked Eye upon the Velvet.

³ Under this Skin even the most corpulent People have no Fat, which would have suppressed the Reflexion of the sonorous Rays by the subjacent Cartilage, if it resided there but in the smallest Quantity. This we speak with regard to the Wing of the external Ear without including the Lobe.

⁴ The Ear is at Liberty on all Sides, and fastened to one Side of the Head by the Intervention of a tremulous Cartilage : that is to say, one of the most elastic Parts in the Body, namely, a Cartilage is conjoined to one of the hardest Parts, the temporal Bone, so as to produce an Organ the most apt to reflect or return sonorous Rays together.

⁵ Which ever way the Head is viewed, either one Ear or the other always offers itself to the Sight ; nor does it matter much whether you look
either

either before or behind or sideways. In whatever Course therefore the sonorous Rays extend to the Head, they must necessarily reach the Ears on one Part or the other, which being elastic Cartilage will reflect into the Ear many sonorous Rays which come from Points trembling with those external Sounds, or their eighths, fifths, or thirds, by which new Sounds being produced will increase the original Sound (§. 547). Hence therefore we are furnished with two Ears; for if we had but one many of the sonorous Rays would be lost; and hence those People who have lost the Use of one Ear, are obliged to move their Head different ways, to take in the Sounds which come from every Side.

§. 549. But in the Figure of the external Ear, there are many Particulars which deserve to be remarked: such as its considerable Eminence, being raised on each Side above the Os temporale, by which scarce any sonorous Rays can escape either one Ear or the other; and its three *spiral*¹ Ridges or Folds, which by their Fabric, Position, and Course, being inclined, intorted and meeting together, occasion the sonorous Rays emitted from any Point to be received by one of the Ears or by both in a sufficient Quantity, where being *reflected*² without Alteration they are then united together, and drove through the external Concha or Shell-like Cavity in the Wing of the external Ear.

¹ These spiral Ridges with which the human Ears are furnished, supply the Deficiency of their Motion, which we observe to be much greater in the

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the Ears of other Animals. For in every human Ear there are three spiral Ridges or Eminences of the Cartilage disposed in such a Curve, that there is a free Passage from one into the other, so as to reflect the sonorous Rays from the exterior Zone or Ridge to the interior, from thence into the third, and from thence again the Rays are determined into the Concha. The Ears are thus formed, because they are not erected perpendicularly ; for if they were so framed by Nature, they would reflect the sonorous Rays out again from the Ear ; but by this Inclination of the Ridges towards the internal Cavity of the Ear, the sonorous Rays which fall upon them, are directed inward to the auditory Passage. I took off the Impression or Figure of the Ear in Wax from a Person who had that Sense in the greatest Perfection ; and to my Surprize I observed, that if a Line was drawn from any sonorous Point to any Point of the protuberant Cartilage in the external Ear comparing it with a right Line, the Angle of Reflexion measured equal to the Angle of Incidence, and that the last Reflexion always fell upon the auditory Passage after many and often repeated Incursions, so that the common Focus of the Curves described by the Eminences falls in the auditory Passage. I once made it the Business of a whole Year to explain this beautiful Theory. The same Fabric was also imitated by *Dionisius* the *Sicilian* Tyrant in the building of his Prison ; for he made it perfectly spiral, and placed the Prisoners in the Center of the Spire, by which means the Words which they spoke with a low Voice were capable of being heard as if they had talked aloud. But the Ears of Brutes have not these spiral Eminences, but instead thereof their Ears are moveable. In the Horse and most Quadrupeds, the Ear re-

sembles

seemles an oblique Section of a Cone, so as to admit only the Air in their Fore-part. But the Horse and other Brutes being provided with Muscles, are capable of directing their Ears every way at pleasure towards that Quarter from whence the Sound comes, that the Animal may be capable of hearing more distinctly any obscure Sound. Even in general it is a Rule, that Animals which have spiral Ridges in the Cartilages of their Ears do not move them, and the Reverse; except some few Persons who, like *Midas*, have such a Motion in their Ears. Add to this, that in Man the Head is extremely moveable, so that he can readily turn it upon the slightest Occasion towards any Sound which requires his Attention.

² I must confess my Opinion to be different from that of most Writers, concerning the Reflexion of Sounds. For it is commonly supposed, that all Sounds indifferently may be reflected from any opake Body. But I am persuaded that the Number of Sounds are definite and determined by the Creator of all Things. But these definite Sounds falling upon such Bodies which agree with the Tension of that Body which gave Rise to the Sounds, occasion similar Tremors in those Bodies, which is what we usually call a Reflexion of the Sound. Hence therefore among harmonical Bodies, one of a lower Tone never trembles with a Body of a more acute Tone. But if you enquire for the Reason, why some Bodies sound together, and others do not at all tremble; it is to be derived from the Number of Undulations which are formed in a given Time. We say two Chords are harmonical, if the Number of their Vibrations in a given Time is the same in each; and the next most perfect Harmony after an Unison, is that which has more than half as many more Vibrations
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in the same Time, namely, an Octave higher than the former, &c. Hearing then is an harmonical Vibration or Trembling of our Ear, struck with the sonorous Body.

§. 550. But the *Opening* ¹ of this concous Cavity, being elastic and free on all Sides, is furnished with two or three *Muscles* ² behind, with one broad above, and a thin one *before* ³; by the Action of which Muscles the Concha may be flattened, expanded, stretched, and adapted to receive the several Tremors which produce Sound; and it is so disposed, that it can more closely unite the sonorous Rays, or else disperse and scatter them, so as to moderate a strong Sound, and increase a weak one, as there is Occasion.

¹ This Aperture is the Beginning of the internal Part of the external Ear. For the Organ of Hearing consists of two Parts, the one external, described before (at §. 549.) together with the Meatus Auditorius (§. 551.) and the Membrane of the Tympanum (§. 552.); but the internal Ear receives Sounds from the external as through a Funnel, by an Aperture which is commonly called the Meatus Auditorius; but the internal Ear is composed of the Cavity of the Tympanum with the Caverns of the Os Petrosus, namely, the semi-circular Canals and the Cochlea.

² The posterior Muscle of the external Ear is threefold, but moves only the Concha, and presses the same backward, so as to dilate the Way to the auditory Passage. When this Muscle is relaxed, the Cartilage of the external Ear restores itself by its own Elasticity, by which the Concha

is

is again contracted : and thus the Cavity of the Concha is enlarged or diminished, according as the Variety of Sounds require.

³ This anterior Muscle contracts the Concha, antagonizes the former, and assists the Elasticity of the Cartilage of the external Ear. This elastic Nature of the Concha has been clearly observed by *Valsalva* and *Morgagni*.

§. 551. The Meatus Auditorius is a *Tube* ¹ composed partly of Cartilage and partly of Bone, lined with a *Membrane* ² like that before-mentioned (§. 548.) becoming gradually thinner, is extremely nervous, and defended with a viscid Water and *Wax* ³ transuding from the subjacent Glands, whence it is extremely well adapted to convey Sounds from without inward without changing or *corrupting* ⁴ them ; but the Obliquity of this Canal increases its *Surface* ⁵, and multiplies the Points of *Reflexion* ⁶ ; also a cartilaginous triangular *Tongue* ⁷ stands erect and tremulous in the Cavity of the Concha, and more especially opposite to the Entrance of the Meatus Auditorius, and being furnished with a proper Muscle, it by a wonderful Mechanism conduces to determine all the sonorous Rays which fall upon the Concha, to enter the auditory Passage without flying back again, being reflected inward on all Sides. The Figure of this Passage is tubular, in Part cylindrical and Part elliptical, ascending and descending in a serpentine Course, and again arising, it terminates in the Membrane of the Tympanum, serving

erving to increase the Reflexion of Sounds, and determine all the collected Rays to fall in the middle Center of the Tympanum without any sensible Clashing.

¹ It is in reality a Trumpet or phonergetic Tube, sonorous, narrow, elliptic, conical or conoide, being a hollow Body, a Section of which is an Ellipsis. Part of this Tube is the broad cartilaginous Ear, but the auditory Passage is that Part which increases the Power of the Sound, lined with a Cartilage which is extremely well adapted to reflect Sound (§. 548.)

² The Skin which lines the external Ear is extended by degrees into the auditory Passage, expanding itself with the Canal so as to form a Sack equal to the auditory Passage itself; but by degrees becoming thinner, is very fine where it covers the external Surface of the Membrane of the Tympanum. It is not only very tense, but also very thin and nervous, insomuch that no Pain is more intolerable, than when an Inflammation invades the Meatus Auditorius; for then the numerous small Nerves which are here naturally very tense, are yet more distended by the inflammatory Tumor so as to be ready to burst, and produce the most acute Pain.

³ The ceruminous Glands of the auditory Passage were first described by *Du Verney*. For when that Anatomist removed the exterior Membrane of the Auditory Passage, there appeared in the opposite Part very small oblong Cryptæ or Cells, which contained a pellucid and somewhat oily Water, which transuding through the open Ducts of the Cryptæ into the auditory Passage, is there by Warmth and Stagnation digested and inspissated

into an yellow and bitter Wax, as we extract it from the Ear, though it has no such Bitterness at its first Secretion. The Usefulness of this Liniment in defending the sensible Membranes of the auditory Passage, is very great and almost incredible. If the Ear is entirely destitute of this Liniment, the internal Membrane becomes dry, rigid and distended so as almost to break the Nerves, and be not far from producing a perfect Deafness. So long as this mild Liniment defends the sensible Membranes from the Air, they all continue flexible and perform their proper Offices; but when it is collected in too great a Quantity, the short Hairs of the auditory Passage having their usual Increase suppressed by the resisting Liniment, are incurvated inward, and irritate the sensible Membrane of the Meatus Auditorius, whence follows an Itching, which obliges the Person to pick his Ear; but brute Animals from the same Cause rub their Ears against Timber or Stones that are next adjacent. Without this Precaution Deafness might ensue: So great is the Usefulness of these small Hairs. But this kind of Deafness may be cured by injecting Water mixed with a little Soap and Sal Ammoniacum, by which the retained Wax being softened is discharged in the Form of a Tent.

⁴ It is demonstrated by the Laws of Sound, that it diffuses itself every way from the Mouth of a Person speaking, or from any other Instrument, spreading itself to all Sides in right Lines, which resemble the Radii of a Circle. The Ear therefore of any Person which is placed within the Area of this Circle or Sphere of the sonorous Rays, will receive so many of them as can be contained in a Cone, the Basis of which is the external Ear, and its Apex the sonorous Point; while the other Rays escape or fall off from the Side of the

the Ear. But the Strength of Sound depends upon the Number of sonorous Rays which are contained in a given Cone. If now we form a Machine which can receive a great Number of sonorous Rays, reflect them together, and afterwards direct them into a Focus; then the Strength of the Sound will be increased in that Focus, in the same manner as the Force of Fire collected by a convex Glass, is increased in the Focus; and by this means the smallest Sound may be so changed as to affect the Sense of hearing, in the same manner with the strongest. Of this Nature is the Speaking-Trumpet, which Instrument is composed of a narrow Part applied to the Mouth, from whence it spreads into a diverging Cone, whose elastic Sides receive the whole Sound which comes from the Mouth: but the sonorous Rays are reflected by the elastic Sides of the Instrument, and the Angles of Reflexion being equal to the Angles of Incidence, after many Reflexions the sonorous Rays pass out into the open Air, not diverging but parallel. By this means the Sound of a Voice may be so increased as to be heard at the Distance of a Mile and a half by a Person who is in a right Line; for those who are on either Side perceive nothing of the Sound; which if it had been emitted from the naked Mouth, would have been lost at the Distance of a few Paces or Ells. Even leaden Pipes which are not elastic and only cylindrical, do yet reserve the Sound of the Voice, that when a Person speaks at one End, it may be perceived by the Ear applied to the other End, even at the Distance of a quarter of a Mile. But such a Tube or Trumpet as that before-mentioned, is the Meatus Auditorius in an adult Person; for in an Infant that has not been long born, this Passage is little or nothing, the Membrane of the

Tympanum being placed immediately behind the Ear; and covered over with a thick scaly Matter or Skin; which by the receding of the Membrane of the Tympanum backward, and the Elongation of the auditory Passage is cast off by a kind of Suppuration. The longer the Animal lives, the Membrane of the Tympanum recedes the farther back, and the Meatus Auditorius is also more elongated. This Covering upon the Membrane of the Tympanum was necessary in Infants, that they might not be continually affected by the Action of strong Sounds, by which their tender Nerves might be easily convulsed. It is therefore a detestable and unhappy Practice, in those who endeavour to divert young Infants with the Noise of Guns, and shewing them strong Lights, by which the whole Brain and nervous System may be put into Tremors to the Destruction of the unhappy Infant. But if Wax is poured into the Ear of an adult dead Body, and afterwards taken out whole when it is cold, by dividing the Bone without injuring the Figure of the Wax, you will have a perfect Trumpet, whose Extremity is without any Aperture towards the Membrane of the Tympanum.

⁵ The Meatus Auditorius could not descend very deep into the Cranium, for it would have penetrated its Cavity and the Brain; and therefore to render it the longer and increase its Surface, it was necessary for it to be oblique. But long Tubes, especially those which are contorted, wonderfully increase Sound; thus the *French Horn* which is spiral, gives a very strong Sound; and Trumpets for War ought to be very long in order to afford a strong Sound. But lest their great Length should render them incommodious, they are inflected or folded together, that the long Tube may
be

be contained in a small Compass. The Design is almost the same with respect to the Obliquity of the auditory Passage, which first ascends then descends, and afterwards ascends a little again; so that its small Depth is compensated by the greater Obliquity. But all these Rays which are directed by the external Ear to the auditory Passage, meet together at last without Alteration in a Point, namely, upon the Membrane of the Tympanum, which shuts up the Meatus Auditorius of an elliptic Figure like the Passage itself; the Focus therefore of the sonorous Rays falls upon this Membrane, upon which the whole Strength of the Sound is concentrated, which was conveyed thither by the external Ear. This results from the Properties of an elliptic Tube. At the Court of *Tuscany* there is an elliptic Portico, in which if a Person speaks against the Wall with a low Voice, every Word that he whispers will be heard distinctly by a Person who stands in the Focus of the Ellipsis, while those who stand without the Focus hear nothing at all.

⁶ The Writers upon philosophical Subjects are the most surpris'd at this Phænomenon, namely, that we should hear a simple Sound, which yet is demonstrated to be composed of an infinite Number of other reflexed Sounds. For Sound is reflected a thousand times from one Side to the other of the auditory Passage, as well as in a Trumpet, till at last it converges together into a Point, and continues strait forward, as if it came from that last Point. But all these Sounds are represented to the Mind as but one. Music will be able to remove all these Difficulties: for it is most true, when we speak, or when any Instrument excites a Sound, there follows an infinite Number of Resonances or Echoes; but yet those Resonances are

not in the least distinguished by the Ear, which perceives only the single Tone. For an Echo is not distinguished unless it returns from a certain determinate Distance. If a Wall is a thousand Feet distant from the Mouth of the Person speaking, one may then hear the Return of each Word, or as it were the Image of the same, which we call an Echo; for the Sound passes in one Second of Time to the Wall, and in another returns again, so that there is time enough for one to distinguish the returning from the primitive Sound. If now the Distance of the Wall be diminished, suppose at the Distance of an hundred Feet, and then to the Distance of ten Feet, in that Case the Time of the Passage of the primitive and reflected Sound to and from the Wall is so short, that the Idea of the former is not out of the Mind when the latter returns; for the Images or Ideas of Objects impressed upon the Sensory do not always instantly vanish, nor do we distinguish those which follow each other more nearly (§. 541.) Therefore the reflected Sounds are all of them conjoined with the primitive, so as to afford the Idea of one single Sound. I said before at §. 547, that the Chord B is in Harmony with the Chord A, and will tremble together when A and B are distant one Octave. If two such Chords sound together, we hear but one Tone, because the greater and the less of the same Kind are confounded together so as to be indistinguishable. In the same manner in our hearing, all Sounds which arise from Bodies in Consonance with the primitive Sound, are joined together into one, so as not to be distinguishable from the primitive Sound with which they agree. If this was not true, we should have been certainly created unhappy by Nature, since instead of one Sound we should hear an infinite Number of Discords, or disagreeable Clashings of Sound. But by
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the former, that is, by the Vicinity of the reflected Sounds, Nature has secured our Hearing from being disturbed by Echoes ; and by the latter, that is, by the harmonical Consonance, we are secured from the disagreeable Tremors and Clashings of the Air.

7 At the Beginning of the Meatus Auditorius is placed a tremulous triangular Body, with which the whole Aperture of that Passage may be closed, so that a Man cannot be able to hear any thing with that Ear. This triangular Body or Tongue is capable of being erected more or less by the small Muscles of *Valsalva*, so that we may be able to moderate the Opening of the Auditory Passage at pleasure, lest when the sonorous Rays arrive to the Ear in too great a Quantity; they might destroy the Organ of Hearing; whereas by diminishing the Aperture, Part of the too powerful sonorous Rays are excluded. The Action of this Part or Safeguard to the Ear is perceptible to the Eye without Difficulty, when after seeing the Flash of a great Cannon we prepare our Ears to receive the great Shock and Noise that is to follow. But this Part which is called the Tragus is furnished with another Muscle antagonizing the former, by which the Tragus is drawn outward, so as to enlarge the auditory Passage, when we endeavour to hear any Sound accurately and distinctly.

§. 552. The *Membrane* of the Tympanum is composed of three Coats or Lamellæ, the middlemost of which is very full of small Vessels, but the outermost of them have scarce any Vessels ; and they are placed so obliquely, as to incline above towards the Auditory Passage, and running out from below, forming

an obtuse Angle above with the Meatus Auditorius, and an acute one below ; which increases thus the Superficies more than if it was spread perpendicularly : by this means there is a larger Compass for receiving more sonorous Rays to fall upon the Tympanum, upon which the tremulous Concussions are multiplied ; but more especially it determines them to run together into the Center of this Membrane, so as to render it more easily tremulous ; but since the exterior Lamella is membranous from the Meatus Auditorius, and the interior Lamella is derived from the Membrane which encompasseth the Tympanum, it is evident that this Membrane hath a great *Communication* ² and Consent both with the external and internal Parts of the Ear. The middle Coat may perhaps arise from the Expansion of a *nervous* ³ Membrane.

¹ The Membrane that lines the auditory Passage recedes inward on all Sides from the Extremity of the same Passage, and meeting together in opposite Parts forms a blind Sack, and by that means closes the bony Passage. To the Bottom of this Membrane is again applied a Membrane from the Pericranium full of Vessels, and another from the Periosteum of the Cavity of the Tympanum. So that the exterior and interior Membrane is derived from the Periosteum, betwixt which is the vascular Membrane. Thus three Membranes concrete together and form the Tympanum, as *Ruyfch* formerly declared to us, though he has since made the Tympanum to consist of but two Membranes. I gave him to understand that he

was

was in the Wrong to detract from this first Opinion; for all Injections do not succeed equally well.

² All the Nerves in the human Body communicate together in a surprising Manner. From an Irritation of the Nose the Diaphragm itself is convulsed, and Sneezing follows from the Communication of the intercostal Nerve with those of the Neck, which send out a Branch to the Diaphragm. In the Glans Penis of a calculous Patient there is an intolerable Itching, because the Stone irritates the Membrane of the Bladder, which is continued through the Urethra, and lines the Glans itself. But Tremors and Vibrations are most easily communicated through Membranes which are so very tense, and endowed with such an Elasticity as the Tympanum.

³ That this Membrane is nervous, we are persuaded from the almost convulsive Pain which follows from an Inflammation of it.

§. 553. The strict Application of this Membrane, the Tympanum, to the *Edges* ¹ of the bony Passage or Cavity, together with its Thinness, Driness and Laxity, accompanied with a Concavity towards the auditory Passage, and a Convexity towards the Os petrosum, and the Malleus being fixed to it, teach us that this Membrane prevents the Entrance of the *Air* ² from the auditory Passage into the internal Ear; and that Dirt, Humours, Insects, Dust, and the like, are here embarrassed in the Ear-Wax, and exciting a Titillation, chiefly by moving the small *Hairs* ³ which are here seated, they are again cast out;
also

also that the sonorous Motions or Vibrations may be *transmitted* ⁴ to the Cavity within the Ear; and perhaps something of an obscure Sense of hearing may be performed in this Membrane itself, namely, the Tympanum.

¹ The whole Circumference of the Membrane of the Tympanum is inserted to the bony Ring, which has a Deficiency only in one Part, through which passes that wonderful Muscle of *Aquapendens* to the Tympanum, which has been since discovered and restored by *Cowper*. This Insertion of the Tympanum into the Margin or Sulcus of the bony Ring, keeps it extremely tense in the same Manner as the Parchment is extended upon the musical Instrument of War, which we call a Drum, from whence this Membrane derives its Name, preserving and augmenting the Sounds which strike upon it. For upon whatever Part the Tympanum is struck, Tremors are conveyed from that Point as through Radii to the Periphera of a Sphere. But yet this uniform Tension of the Tympanum is not of itself sufficient for hearing; for if it was only strained to the harmonical Tension of one Sound, it would only tremble from that Sound, with its Octaves, Fifths, and Thirds, greater and less (§. 547), so that we should not be capable of hearing any more than this one kind of Tone or Sound. It was therefore necessary to contrive a Mechanism by which this Membrane might be more or less strained or tightened, according to the Variety of Sounds, that it might be capable of coming into Unison, or correspond harmonically to all Sounds. In the same Manner a single musical Chord will express all Sounds only by different Degrees of Tension. For if the
Chord

Chord sounds lower than is just, by straining it a little the Sound will be more acute, and by doubling the Tensity it will sound an Octave higher than before; so that by only turning round the Screw from one Octave to another, it may be raised through all the intermediate Sounds.

² That the Tympanum performs this Office, we learn from a practical Experiment. If any one is hard of hearing, and applies to a Physician to know whether the Tympanum is injured, the Patient is ordered to take a deep Inspiration, and shutting his Mouth and Nostrils, to make the Effort of Expiration, by which the Cheeks are distended with Air, which insinuates through the *Eustachian* Tube to the Cavity of the Tympanum; and if that Membrane is broke, it escapes through the external Ear, and denotes that the Deafness is incurable. But if the Air does not escape through the external Ear, being confined by the entire Tympanum, there are Hopes of relieving the Patient. It was necessary for Nature to furnish the Ear with this Membrane, as a Safeguard to the Muscles, Ligaments, and Perioste of the small Bones which are contained in the Cavity of the Tympanum, that they might be kept soft, pliable, and fit for Motion, suspended as it were in a vaporous Bath secured from Insects, and preserved from the Drought of the external Air.

³ These Hairs grow very speedily, and have been described by *Du Verney*. When they are compressed or incurvated, they are thrust into the Membrane which lines the auditory Passage, so as to occasion an Itching which is intolerable to every kind of Animal, and gives them Notice to remove the irritating Cause as soon as possible. If Nature had not provided us with this necessary Sense, we might have been easily deprived of

of our Hearing without any Warning, as the Husbandmen frequently are, when the auditory Passage is filled full of Dust; but the Sordes being dissolved by injecting with a Syringe, the Disorder is removed.

⁴ To transmit the sonorous Impressions not thro' an Aperture, but by similar Tremors in the Membrane of the Tympanum, which excites the same Tremors in the Air included in the Cavity of the internal Ear. How much Influence Sound has in drawing the most solid Bodies into similar Tremors, is evident from the musical Organs of Churches: when the lowest Pipe of that Instrument is blown, it sends forth such a Tremor or Vibration as in a Manner draws the whole Pavement and Pillars of the Fabric into a similar dancing Motion. In the same Manner large Cannons which are used in the Besieging of Cities, shake the whole Surface of the Earth to the Distance of some Miles, so as to make a Bullet dance that is placed upon the Parchment of a Drum.

§. 554. The Malleus is *firmly* ¹ applied to the Back of the Membrane of the Tympanum, with its Handle extended almost to the *Center* ² of that Membrane; and at the same Time the Head of this Bone is moveable in the Bony *Sinus* ³, while the other Surface of its Head is furnished with two small *Protuberances* ⁴ and one Excavation, being connected by the Articulation called *Ginglimus*, with two Cavities and one Protuberance of the Body of the Incus, which is otherwise freely suspended in the same Cavity by the artificial Insertion of three Muscles into this Malleus; here also
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the *external*⁵ Muscle which relaxes the Membrane of the Tympanum first presents itself, arising fleshy from the upper Part of the Margin of the external bony auditory Passage, and is inserted tendinous, running under the Membrane which is replenished with ceruminous Glands, from whence its Tendon ascends to the upper Part of the Membrane of the Tympanum, where it passes through a Sinus or Deficiency which is left in the Margin of the bony Ring, and enters into the internal concave Cavity; where ascending even to the Protuberance betwixt the upper and lower Apophysis of the Malleus, it is there inserted: from whence it appears that this Muscle draws the Malleus and Membrane of the Tympanum towards the auditory Passage, by which means the Tympanum is rendered smooth and lax. 2. In the second Place we here discover the *external*⁶ Muscle, which arising tendinous from the external Part of the *Eustachian* Passage, upon which it lies fleshy, ascends afterwards backward and enters the Cavity of the Tympanum, passing through an oblique Sinus or Notch, above the bony Margin of the Membrane of the Tympanum, and inserts itself into a slender Process of the Malleus, and is particularly extended into a very long, slender, flexible and elastic Production, which was discovered by the laudable Industry of *Raw*, who has taught us that this Muscle is inserted by a very broad Expansion of Fibres for an extraordinary Use; namely, that it might determine and draw the thicker Part
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of the Malleus with the Membrane of the Tympanum, in many different *Directions* ⁷ towards the Meatus Auditorius. 3. In the third Place we discover the *internal* ⁸ Muscle of *Eustachius*, whose Fibres arising from the anterior Side of the Cartilage of the *Eustachian* Passage, is afterwards contained in and runs through a bony Furrow, from whence it ascends laterally to the upper Part of the *Eustachian* Passage; from whence departing, its Tendon rises up near the Fenestra Ovalis, and turning back about a bony Part like a Pulley, it is inserted into the Malleus in its back Part, under the Insertion of the external Muscle of the same Bone; when this Muscle contracts, the Malleus and Membrane of the Tympanum is drawn towards the Os petrosum, by which means it is tightened and rendered concave: and from all this we learn that the Malleus is like a Lever applied to the Membrane of the Tympanum, and being moveable in a Moment presses upon the Sinus or Excavation in the Margin, as being fixed to a Basis sustaining its Rotation, in which it is drawn by the Contraction of one, two, or three Muscles; it may therefore, 1. expand or *tighten* ⁹ the Membrane of the Tympanum, relax the same, render it convex, hold steady and suspend it in various Degrees of Tension and in different Directions. 2. It may also by this means vary the internal Space of the concave Cavity, so as to draw the Air in, compress or expel the same according as the *Eustachian* Passage is at the

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the same Time either open or *shut* ¹⁰. 3. By this Means therefore the Membrane of the Tympanum may be adapted to receive the sonorous Vibrations or Tremors to be communicated to Bodies *harmonically extended* ¹¹ or stretched, and that it may easily communicate them to the Incus, as we are taught by the mathematical Doctrine of Harmony or Music.

¹ The Malleus is so firmly attached to the Tympanum, that its Membrane seems to be spread over the Process of that Bone, so as to include it as it were in a Duplication. It is to be observed that the Moderns improperly call this Membrane the Tympanum, since by that Name the Ancients understood also the whole Cavity of the Os petrosum in which the small Bones are included; distinguishing this by the Name of the Membrane of the Tympanum, manifestly so called from its Similitude to the Kettle-Drum.

² But it is not extended beyond the Center of this Membrane; and therefore it forms a moveable Radius attached to this Center, that by being drawn inward it may tighten the Membrane, and render it more convex towards the Os petrosum, and relax the same, or render it more flat, by thrusting it farther towards the auditory Passage.

³ This bony Sinus is seated in that Part where there is a Deficiency in the bony Ring of the Membrane of the Tympanum, in which Sinus the fixed Point or Hypomochlion of the Malleus is stationed, upon which it moves and inclines one way or the other.

⁴ The Articulation of the Malleus with the Incus is very much like that of the Knee, where the Tibia

Tibia is collected to the Femur, and admits only one Kind of Motion. By this Manner of Connection it happens, that the Malleus cannot be moved upon its fixed Point without moving at the same Time the Incus which is freely suspended.

^s *Fabricius* of *Aqua pendente* first described this Muscle in an elegant Treatise upon that Subject, which is become obsolete or neglected in our Days. It arises with muscular Fibres under the first Tunica of the auditory Passage, and passes through the Deficiency in the bony Ring above the Membrane of the Tympanum into the internal Ear. It draws the Malleus, together with the Membrane of the Tympanum, towards the Meatus auditorius; so as to render the latter more flat, when it has been render'd convex or protuberant towards the Cavity of the Tympanum, opposite to the auditory Passage; from which Action it necessarily follows, that the Membrane of the Tympanum must be relaxed by this Muscle. For every Line which unites two Points is the shortest when strait, and must be elongated whenever it is formed into a Curve, while the Points remain at the same Distance: and, on the other Hand, a curved Line joining two Points must become shorter when reduced to a strait Figure. But a Fibre being elongated is tightened, and relaxed when it is shortened; and therefore it follows, that the Membrane of the Tympanum being rendered less convex must be relaxed, which can be the only proper Action of this Muscle. So often then as this Membrane is too tense to be in Harmony with the more grave Tones, it is then reduced to Unison by the Action of this Muscle, which relaxes the same while the other Muscles are at rest. Thus those grave Tones will be audible, which a greater Tensity of the Membrane would not have transmitted to the Mind.

Mind. This same Muscle also increases the Capacity or Cavity of the Tympanum, giving a Passage to the Air coming through the *Eustachian* Tube into the internal Concha.

⁶ The first of the internal Muscles arises from the Os petrosum, from a Sulcus in the outer and anterior Part of the *Eustachian* Tube; and after proceeding a little way forward, it ascends obliquely and enters the Sinus osseus; from whence again it passes out, and is inserted by a small Tendon into a Process of the Malleus. When this Muscle acts, it draws the lower Part of the Malleus, together with the Membrane of the Tympanum to which it is attached, inward and forward, rendering the same more convex, and of an harmonical Tensivity with the more acute Sounds.

⁷ The second of the internal Muscles arises from the anterior Part of the Side of the Cartilage belonging to the *Eustachian* Tube, and then passing through a small Excavation in the Os petrosum, it runs along laterally to the upper Part of the Opening of the *Eustachian* Tube; and from thence descending perpendicularly, it is inserted into the same Part of the Malleus with the former. When this Muscle acts, it draws the Malleus and Membrane of the Tympanum directly inward, and tightens the same. These two Muscles when they operate conjunctly, stretch the Membrane of the Tympanum in such a manner, that it is susceptible of the least Variation in Motion, and retain it in such a perfect Equilibrium, that it is put into Tremors by the least Vibration of the external Air acting but for a Moment. And thus conditioned is the State of the Ear in those People who are inclined to Music; whereas those who cannot thus adapt their Ears to different Sounds, can never make any Proficiency in Music. But others continually

sing the same Tone which they hear, and are capable of repeating Songs as fast as the Eye can take them without any Defect in the Tone.

⁸ The first of the internal Muscles is furnished with a very long, flexible, and elastic Process, of a greater Extent than all the rest of the Bone, in order that it might be more conveniently inserted into the Malleus. The Discovery of this Process is owing to *Raw*, although it is said to have been demonstrated and discovered by one *Foly* in the Writings of *Bartholin*. But this Muscle is inserted the whole Length of the Process, by which means it is capable of moving the Bone and tightening the Tympanum in different Degrees; whereas, if it was inserted into a single Point of the Bone, it could only give it one Degree of Tensity, but as it sends forth a long Series of Fibres into the Bone, it may be capable of drawing the same, more or less, laterally in an infinite Number of Degrees and Directions, according as this or that Series of Fibres shall prevail. Others think this Process to be rather a sort of Bone articulated to the Malleus, and which by Age grows together with the same, as we usually observe in the *Os styloides* and the *Os temporale*.

⁹ The shorter any Chord is, the less Degree of Tension it requires to produce a Variety of Sounds; but the longer the Chord, so much the greater Force it requires to vary its Tone. But in the Ear there are small Fibres instead of Chords, which yet may be stretched harmonically through different Degrees. As this was necessary, the Membrane of the Tympanum is therefore provided with moving Muscles and Levers, which are capable of tightening the same various Ways. All these Muscles are placed by Nature in a Part to which the external Air has no Access. *Eustachi-*

us and *Aquapendens* have demonstrated, that the whole Cavity in which these Muscles are disposed is replenished with warm and moist Vapours. So soon as the external Air penetrates to the small Bones of Hearing by an accidental Rupture of the Membrane of the Tympanum, all the Muscles are dried up; and instead of distinct hearing, a confused Noise is perceived, so that the Patient can neither distinguish articulate Words nor musical Notes, till at length the whole Sense is entirely destroyed.

¹⁰ When the *Eustachian* Tube is closed, no Air can pass into the internal Ear; but then the Membrane of the Tympanum is struck by some external Sound, and by that means rendered more convex, it compresses or condenses the included Air in the Concha, that the Tremors may be more powerfully communicated to the internal Ear. But when the *Eustachian* Tube is open, the Membrane of the Tympanum is pressed out by the Air which entered through the Tube; whence the Air which conveys the Sound through the auditory Passage is resisted, and consequently the Perception of it is diminished. The Tube is therefore closed or shut in order to the more distinct Perception of Sounds, but is relaxed and opened in order to diminish their Force; whence it appears that the Membrane of the Tympanum is moved, as well by the internal Air as by the external.

¹¹ A simple Percussion of the Air, which is a Particle of Sound, being repeated a determinate Number of times by the Tremors of the sonorous Body, forms a determinate Sound. When these Tremors are very swiftly repeated, the Tone is said to be acute, but grave when the Vibrations of the Chord are slow; for the same Chord being moved slowly will yield a great Tone, and being put into quick Vibrations, it will also yield an

acute Tone. Now when a vibrating sonorous Body communicates its Percussions to the Air, and there is any adjacent Body which by some Impulse will yield the like Number of Vibrations in the same time, in that Case this other Body will likewise begin to vibrate at the Sound of the other, and two such Bodies are said to be in Concord. But if the Body A communicates its Tremors to the Body B with which it is in Concord; and again the Body B likewise communicates its Tremors to that of C with which that is in Concord; then in that Case when A sounds, C will also sound in Consonance: but when the Body A sounds by a Stroke, while the quiescent Body B does not produce the same Number of Tremors in the same time, in that Case, when one Body sounds the other will not be affected, so that the Bodies A and B may be said to be in Discord. From hence arises the Reason why the Malleus is qualified for different Motions by particular Muscles. For Sounds differ from each other in an infinite Number of Ways, as well in their Kinds, as in the numberless Degrees of Gravity or Acuteness. Yet ought the Membrane of the Tympanum to be capable of being in concord with all these different Sounds in order to return the like Tremors, and communicate them to the internal Ear, that they may be represented to the Mind as they come from without. This Concordance of the Membrane of the Tympanum with the great Variety of Sounds, is produc'd by the Malleus with its proper Muscles, which produce an infinite Number of Degrees of Tensity in the same Membrane. The Tympanum then may be determined to all those Degrees of Tone with which the Chords of the Tympanum are in Consonance. But these Sounds are infinite in Number and Variety which renders this Matter
not

not a little surprising. The Chords of the Membrane of the Tympanum are very short, the whole Extent of that Membrane being no larger than one's Nail; and yet can those short Chords increase the Celerity of their Tremors to produce more acute Tones, so that the Membrane of the Tympanum can bear all Tones, which are not more acute than those which arise from a Chord equal in length to the Diameter of the Nail. But when any Chord trembles which is shorter than the Diameter of the Nail, so as to yield more swift Tremors than the Membrane of the Tympanum, it then produces a squeaking, which affects the Teeth and adjacent Parts so as to be almost less tolerable than Death itself, even in Men who have this Sense duller than usual, the Membrane of the Tympanum being then stretched so as to be near breaking: such short Chords as these are tense Particles of Iron, as when thin Plates of Steel are held fast betwixt two Screws, and filed away on the Edge, as in making Saws.

§. 555. The Body of the *Incus*¹ articulated to the Malleus (§. 554.) presses likewise upon the Sinus Osseus in the Malleus, its shorter Process being freely suspended by a Ligament in the upper and posterior Part of the Cavity of the Concha; while its longer Process is collected to the *Os orbiculare*²; the Articulation also of this Bone with the hollow Apex of the Stapes, with the Connection of the elliptic Basis of the Stapes with the Membrane of the Fenestra ovalis, demonstrate that the sonorous Tremors being impressed upon the Membrane of the Tympanum, may be (by the Assistance

of these four Bones encompassed with their vascular Periostea, and connected by their respective Articulations, suspended freely in the large Cavity of the Concha, and moistened continually by the transuding Humours) communicated unaltered to the Membrane of the Fenestra ovalis, and there make the like Impressions.

The Incus is furnished as it were with two Feet, the former of which is connected by a particular Ligament to a resounding Cavity in the Processus Mastoideus. The other Leg of the Incus rests upon the Basis of the Stapes, all the rest of it being at liberty or freely suspended. Hence it follows, that when the Membrane of the Tympanum excites the Malleus into harmonical Tremors, the Incus must be agitated in the same manner, and communicate the like Tremors also to the Stapes. But the Stapes stand upon the Membrane which shuts the Fenestra Ovalis of the Tympanum, and therefore that oval Membrane must likewise suffer the same Tremors. Nor does the Tremor here stop, for the other face of the oval Membrane looks towards or into the Vestibulum; and into the Vestibulum open the winding Cochlea and five semicircular Canals; and in the Vestibulum again the Pulp itself of the auditory Nerve is expanded naked in the same manner as the Retina is expanded round the vitreous Body in the Eye. A Tremor therefore of the external Air will excite similar Tremors, first in the Membrane of the Tympanum, then in the several small Bones, afterwards in the Membrane belonging to the Fenestra Ovalis in the Vestibulum, and at last in the auditory Nerve itself. But the Tremors are not commu-

nicated

nicated in this manner without some Addition, for they are increased while they pass through the small Bones. For every Body which is in harmony with the Sound that strikes the same, will likewise regenerate a similar Sound. Thus in a Harpsichord, the shrill and vivid Tone does not arise from striking one small silver Chord, but is owing in a great measure to the Concordance of the whole Instrument, which sounds at the same time.

² One Leg of the Incus which rests upon the Stapes, is articulated with the last mentioned Bone by means of an intermediate small Bone, which like a Meniscus is hollow on each Side so as to be freely moveable as well towards the Incus as towards the Stapes. This same Motion could not have been easily obtained in the Articulation of the Incus with the Stapes, without this intervening small Bone

§. 556. Here again the Stapes and Membrane of the Fenestra ovalis may be stretched or tightned by a wonderful *Artifice* ¹, namely, by a Muscle of the Stapes, which arises with a fleshy Body from a Canal or Groove in the Os petrosum at the Bottom of the Tympanum; and then descending with a small Tendon, it is connected to the head of the Stapes, so that by contracting in an oblique manner, it depresses one part and elevates the opposite part of that small Membrane.

¹ When the Malleus is drawn inward, and the Membrane of the Tympanum stretched, then the Stapes will be moved by the Motion of the Malleus and Incus. But lest the Stapes should recede from the Fenestra Ovalis, and impress its Tre-

mors upon any Part besides this Membrane of the subjacent Fenestra, therefore the Stapes is provided with a proper Muscle of its own, which draws that small Bone towards the Os petrosum. And thus the Membrane of the Fenestra ovalis is equally stretched with the Membrane of the Tympanum; and hence it is that the sonorous Tremors received by the external Ear, are determined to fall upon a tense Membrane of the Tympanum, which being put into similar Tremors agitates the Malleus, Incus and Stapes, which communicate the same Tremors to the Membrane of the Fenestra Ovalis, so that the number of Vibrations of the internal Air correspond to those of the external; the interior Membrane being also stretched in the same Manner as the Tympanum without.

§. 557. Thus Sounds are conveyed without Alteration to this Membrane of the Fenestra ovalis; but that may by the Aparatus before described (§. 554, 555, 556.) be stretched through an infinite Number of Degrees of Tensity, so as to be capable of adapting itself to receive an infinite Number of different Tremors, so as to concur harmonically in the like tremulous Vibrations, and communicate the same to the Cavity of the Labyrinth, for the shutting up or inclosing of which, this Membrane of the Fenestra ovalis is subservient.

§. 558. The large internal *Concha* ¹ of an elliptic Form communicates with the cellular Cavity of the *Processus Mastoideus* ², and with the *Eustachian Tube* ³ which is partly bony and in part cartilaginous, opening with a
small

small Aperture towards the Palate, which is capable of being shut by a cartilaginous semi-lunar Margin, and of communicating with the external Air which is drawn through the Nose or Mouth. This Tube admits the same Air to pass through into these Places, where remaining and being rarified, it may afterwards pass out again and be *renewed*⁴, or else confined and compressed; so that, 2. The same Air may be reduced to the Density of the external Air; and, 3. This Tube serves to convey the *sonorous Rays*⁵ admitted by the Nose or Mouth, that the Person might be capable of Hearing, if the Meatus auditorius should by any means be injured or stopped up. 4. It serves to discharge the superfluous Moisture, which is separated by the *vascular*⁶ Membrane investing these Parts, in order to *clean*⁷ or render them lax and lubricated.

¹ By the internal Concha we understand the Cavity of the Tympanum, which is terminated on that Side towards the Meatus Auditorius, by the Membrane which is now absolutely called the Tympanum, which is convex towards this Cavity, to which the Ancients gave the same Name. Opposite to the Membrane of the Tympanum is placed the Os petrosum, which is quite rough and perforated with two Openings, the one termed Fenestra ovalis, opposite to the Membrane of the Tympanum, and the other called the Fenestra rotunda, which lies behind and on one Side of the former. But in the Os petrosum there are small Excavations here and there placed, in which the Muscles

cles and Vessels are received. And behind these are placed the Cells of the *Processus Mastoideus*.

² This Process is wanting in Infants, but grows up with Age in Proportion to the Head, in the same Manner as we observe the frontal Sinus's absent in a Fœtus; but which are formed by degrees as the Age advances, when the opposite bony *Lamellæ* recede from their mutual Contacts. Within this Process is contained an infinite Number of bony *Lamellæ* variously connected, and leaving intermediate Vacuities or Cells, each of which being lined with its proper Membrane, is a kind of resounding Cavity; but all of them communicate with the internal Concha or Cavity of the Tympanum, by which Mechanism the Resonance or Effect of the Sound is greatly increased. Thus if the Parchment of a Drum was expanded in the open Air without any resounding Cavity under it, it would produce an inconsiderable Sound which would soon perish; but when the same is extended over a hollow Cylinder, under the Bottom of which is a tense Chord, then the same Membrane being struck will yield a strong Sound. In our hearing, the Tremors of the Air are conveyed from the external Ear to the Membrane of the Tympanum, which Membrane being struck, communicates the like Tremors to the Air contained in the Cavity of the Tympanum; these Tremors fall upon the arched Cell of the mastoide Process, where they make a great Resonance. I am indeed not ignorant, that many considerable Anatomists believe this cellular Process to be of little or no Service towards the Hearing, because they find no Cavity in the same in Infants. But for the same Reason I deduce the contrary Inference, and rather believe it to be the more necessary towards the Hearing, which is inconsiderable in the Infant. We know that new born

Infants

Infants are blind, because the aqueous Humour is turbid, which is a great Providence of Nature, lest coming most suddenly out of their dark Habitation the Uterus into a strong Light, they might be struck and convulsed by too strong an Impression of the Light upon this tender Organ of Sense. By the same Providence of Nature, they are also born in some measure deaf, the Membrane of the Tympanum being covered over with another mucous Membrane, and the resounding Meatus Auditorius and Caverns of the mastoide Process being as yet wanting. But by Age the Organs of Sense are hardened more to the external Impressions of Objects; and therefore by a wise Contrivance the Resonance is increased as the Age advances, and as the Nerve becomes less tender, lest our Hearing should desert us too soon.

³ Into the lateral and anterior Part of the Cavity of the Tympanum, opens the Basis of the hollow and conical Tube of *Eustachius*, so shaped that it decreases or grows less as it passes towards the Palate, and at its narrowest Part is inserted with its Apex or End into the Cavity of another conical Tube, the Basis of which is near the Nose in the Recess or Cavity belonging to the back Part of the Palate itself: for this Tube which is denominated after its Inventor *Eustachius*, is composed of two distinct Tubes, the Extremities of which unite together, but their Bases diverge differently. By this Passage the Air drawn in by the Nose, finds a way into the Cavity of the Tympanum, and gives a free Communication with the external Air, lest that contained in the Cavity of the Tympanum, being different from that of the Atmosphere, should be apt to produce Discord in receiving and communicating the Vibrations of the latter when the Air is extremely dry, as we now observe

observe it to a very great Degree [*March 1727*], so as to be useful for the Trial of many natural Experiments; in such an Air, the Trumpet sounds extremely sharp, whereas in a more moist Air, it affords a different and more obtuse Sound. If therefore the dry external Air should become moist without producing the like Alteration in the internal Air of the Ear, we should not hear Sounds as they are in the Air but differently; nor could the internal Air be varied agreeable to the external, unless the *Eustachian* Tube conveyed the external Air into the Cavity of the Tympanum. But the Membrane of the Tympanum propagates the Tremors of the external Air to that which is included, without giving any Admittance to the Air itself. The great Necessity of these Tubes for admitting the Air is evident from Diseases: for *Hippocrates* has left it as an Observation, which is also confirmed by the Experience of *Valsalva*, that in a Quinsy of the Throat and Fauces, the Patient becomes deaf from a shutting up of the *Eustachian* Tubes, by a swelling of the Membranes; and in the Venereal Disease if any Ulcer should be formed at the Entrance of the *Eustachian* Tube, the Use of that Ear will perish; and if the like happens to the other Ear, the Patient may bid adieu to his Hearing.

⁴ The Air which is received into the Cavity of the Tympanum, is there rarified by Warmth, and expands the Membrane of the Tympanum towards the auditory Passage, resisting at the same Time the Tremors of the external Air, by which means it would impede the Hearing, if it was not to be changed or renewed at Times. The Air is renewed or sent into this Cavity by the *Eustachian* Tube, when we breathe with the Mouth very wide open; and hence it is that in gaping we do not hear.

Those

⁵ Those who are perfectly deaf from an Obstruction of the auditory Passage, are yet capable of Hearing when the Sound is immediately applied to the *Eustachian* Tube.

⁶ The Malleus, Incus, Stapes, and little Os orbiculare within the Cavity of the Tympanum, together with the Os petrosum, are all invested with a vascular Periosteum, the small Arteries of which were first demonstrated by *Ruyfch*; from which Membrane the small Bones of Hearing likewise receive thin Ligaments or Capsules investing their Articulations, which together with the Membranes ought always to be kept moist, that they might not become dry or rigid. The Cavity of the Tympanum therefore serves for two Uses; namely, 1. As a resounding Cavity to multiply or increase the Tremors received from the auditory Passage. 2. To serve as a vaporous Bath for preserving the small Bones of Hearing, with their Membranes and Muscles, moist and fit for Motion.

⁷ The Tympanum is cleansed by Sneezing, in which Action the moist Sordes of the Ear being shook off, are discharged through the *Eustachian* Passage; and hence it is that after Sneezing in a Morning, the Hearing becomes more exquisite.

§. 559. But while the Fenestra rotunda closed with its thin and tense Membrane lies open to one Part of the spiral Cochlea, and is placed as it were in the Focus of its elliptic Space, opposite to the Center of the Membrane of the Tympanum; it is from thence evident, that those sonorous Rays which act upon this Membrane communicate their Tremors to the spiral Cavity of the Cochlea, and make their Impressions

Impressions upon the contained Nerve, but perhaps not so distinctly and accurately as those which are communicated to the Membrane of the Fenestra ovalis, by means of the Tympanum and small Bones of Hearing.

§. 560. Whether the *Eustachian* Passage is by the Action of the *internal* ¹ Muscle opened at the same Time, that the Membrane of the Tympanum is drawn towards the same, diminishing the Cavity of the internal Concha? and whether the Aperture of the same Tube near the Palate is *shut* ² with a cartilaginous Valve drawn over by the Contraction of the Cephalo-pharyngei Muscles, preventing any Part of the Aliment from passing this way at the Time of Deglutition? seems more than probable.

¹ *Du Verney* wrote to me, that the small Muscle of the Malleus arose not from the bony but the cartilaginous Part of the *Eustachian* Tube, which he improperly called the Aqueduct, lined with an Expansion of tendinous Fibres; thus it happens that by the same Action of this Muscle, the Membrane of the Tympanum is drawn inward and the Tube opened at the same Time, that the Air which was compressed by the Membrane of the Tympanum may pass from its Cavity into the Fauces. But these Opinions of that Anatomist are not inserted in his Works.

² If it be asked, Why the Aliments which we swallow do not naturally pass by this Tube into the Cavity of the Ear, since Liquors pressed endeavour to escape every way; we may answer, Because the
same

same Muscles which dilate the Pharynx being seated above the *Eustachian* Tube necessarily compress the same, when they contract and swell like other Muscles. But when these Muscles are destroyed by a venereal Ulcer, in that case there are surprising Noises and Pains perceived in the Ears at the Time of swallowing; and even the putrid Aliments have been known to escape through the Tympanum, after corroding that Membrane with the small Bones of hearing, so as to occasion a perfect Deafness.

§. 561. But since also the oval Fenestra or Perforation opens into the hollow *Vestibulum*¹ which is filled partly with the medullary Portion, partly (1.) of the Nerves which arise from the auditory Nerve, and entering through a Foramen in the internal Surface of the Os petrosum, are carried strait forward through small Foramina into the Vestibulum, where they are distributed, defended, and expanded in order through the three semicircular bony *Canals*², from whence they seem to pass out again in a medullary State. (2.) The medullary Portion of the soft auditory Nerve passing through the forementioned Foramen into the Apex of the Cochlea through many small Foramina, from whence they are distributed in slender Filaments through the upper spiral Cavity, and from thence again expending a soft Pulp into the Vestibulum under the oval Membrane: From all which it is evident that the sonorous Rays by the trembling of this Membrane are conveyed, by means of these agitated

agitated Nerves, to the common Sensory, and there excite the *Idea* ³ of Sound.

¹ Nothing is more surprising throughout the whole Body than the Fabric of the *Os petrosum*; it is perhaps above a hundred Times harder than any other Bone, even harder than the Teeth themselves, infomuch that even in the *Fœtus* it is almost like Marble, when all the other Bones are extremely soft; except only that this Bone is also soft, and almost capable of being cut in that Part where it unites with the *Os squamosum*. Into this Bone the Nerve of the seventh Pair, which the Ancients called the fifth, enters; though *Vesalius* neither includes the pathetic Nerve nor the mastoide Processes; but they are taken in by *Eustachius* in his Catalogue of the Nerve. This acoustic Nerve is composed of two Trunks, the one soft and the other hard, termed the *Portio dura* and *Portio mollis* of the auditory Nerve. These two Trunks arising from one common Origin, pass together through a large Sinus in that Side of the *Os petrosum* which lies towards the Brain; but in this large Sinus, the soft Trunk departs from the hard Part of the Nerve, which last is received into a peculiar Canal, which *Fallopianus* has denominated an Aqueduct; which is a very improper Name for this Tube, though it is given by one of the first Anatomists in Europe, *Du Verney*. Through this Aqueduct in the *Os petrosum*, the Nerve at length passes and sends off the *Chorda Tympani*, and passing on through the mastoide Process, it goes out by a bony Canal betwixt that and the styloide Process, sending Branches to those Parts of the Head which require to be very swiftly moved: Whence it seems very probable that these Branches are detached from the auditory Nerve, that the
Head

Head might be swiftly turned towards any Sound. But the soft Portion of the Nerve becomes surprisingly fine in the Bottom of the bony Duct, so that it seems to vanish and terminate in a blind Recess, like as when the Finger is inserted to the Bottom of a Glove. But the Industry of *Valsalva* has discovered five very minute Foramina in the Bottom of this Sinus, which lead into the Os petrosum. Through these very minute Canals the Pulp of the Nerve itself is conveyed into the Vestibulum, and there appears to be the immediate and true Instrument of the Sense of Hearing, even though it is by much the smallest Part in Appearance of the auditory Nerve; for there are only five small Filaments of the auditory Nerve belonging to this Sense, and destined to the Perception of Sounds, all the thick Part of that Nerve being spent upon the Integuments.

² Of these five small Filaments, three of them perforate the Os petrosum, and enter into the three semicircular Canals, which are bony, hollow, and resounding; and in the resounding Cavities of these Canals the three small Nerves are expanded, and at length meet together with the fourth Filament (§. 562.) which entered the Cochlea. But the Vestibulum is a Cavity in the Os petrosum, which follows next under the Membrane of the Fenestra ovalis. If it be asked, Why the three semicircular Canals were formed, we answer, that the three nervous Filaments might be expanded round them in Order without Confusion, and defended from the least Injury by so firm a Support. But why there should be five Openings to the three Canals, or why Nature has reduced their Number to three, is not our Business to say.

³ From all that has been said, it is evident that the Membrane of the Tympanum being struck

harmonically by Sounds, transfers the same Undulations to the Membrane of the Fenestra ovalis; under which Membrane follows the soft Part of the auditory Nerve, namely, the three Filaments which enter into the semicircular Canals, and that fourth Filament which is inflected and spread round the other Winding of the Cochlea. These Nerves therefore tremble by the Tremors received from the Membrane of the Fenestra ovalis struck by the Stapes; and this Tremor in the Nerve is what we call Hearing.

§. 562. But the Fabric of the spiral *Cochlea*¹ appears above all to be formed most admirably, since the *Canalis osseus*, which is conical, makes two spiral Turns and a half upwards from its Basis about its bony Cone, its Apex terminating at the Point of the same Cone; and is at the same Time divided in every Part from the Basis to the Apex by a triangular Partition which severs the same into two equal Parts, the Partition itself being sustained by the Cone, smooth, tremulous, and elastic; on the outward Part which respects the Cone that supports the same, it is a nervous Membrane in some Measure attached to the forementioned bony Parts and partly fixed to the *Canalis osseus*; so that thus these two spiral Cavities do not at all communicate, but the Mouth of the uppermost opens into the Vestibulum, and the lowermost is closed by the Membrane of the Fenestra rotunda; and thus the very tender small acoustic *Nerves*², appear to be every where distributed throughout.

¹ By the Cochlea we understand a spiral Body, which is hollow and of a conical Figure, partitioned into two semi-conical Cavities. The Septum, which divides the hollow Cone into two Cavities, is a triangular Ifoseles; and that Portion of it which belongs to each Cavity, is a right-angled Triangle. For when a strait Cone is divided perpendicularly to its Basis, the Plane which passes through its Center will divide the Cone into two equicrural Triangles, and if the same be divided through its Axis, it will form two equal and right-angled Triangles. Now one of the right-angled Triangles in the Cochlea is bony, and the other membranous or nervous. But again, this whole equicrural Triangle, with the two right Angles of which it is composed, is inflected in the Cochlea round a Cone, so as to describe the Spiral of *Archimedes*; namely, two whole Circumvolutions and a half. This Fabric was chose by Nature for reducing the same into a small Compass; for a Spiral is six Times longer than the right Line about which it is inflected.

² The two Cavities of the Cochlea have each their particular Nerve, which is inflected round their hollow Surface. But there is also another small Filament, which is one of the five Nerves before-mentioned, (§. 561.) which is sent into the winding of the Vestibulum which terminates under the Fenestra ovalis; and therefore this last small Nerve is exposed to the Tremors of the Membrane belonging to the Fenestra ovalis, which receives its Vibrations from those of the Air conveyed through the external Ear to the Tympanum. But the other small Nerve which enters through the Apex of the Cochlea, and is spread through the second Cavity thereof; namely, the winding of the Tympanum inflected or circumvoluted into

two rounds and a half; and this last Cavity terminates at the Fenestra rotunda, in which there is nothing either of Muscle or Bone, but only a thin tremulous Membrane. These two last mentioned Scales or winding Stairs are of great Use. When we do not attend to Sound, the Membrane of the Tympanum is stretched to some particular Degree of Tension, and in that Case a Man who is in Silence and Meditation will distinctly perceive only one Sound, namely, that which is in Unison with the Tension of the Membrane of the Tympanum: but in talking, the other Sound which was indistinctly received escapes the Person, who looking round says to his Friend, I heard you say something but it escaped me. This first confused Perception, which is conveyed to the common Sensory, seems to arise through the Fenestra rotunda, which is a simple Membrane, immutable, and furnished with no Machine to vary its Tension; whence it seems to be the true Organ of indistinct Hearing; which we commonly call a Noise: But when the Mind thus perceives any such indistinct Sound, the Ears are immediately erected, that is to say, the Tympanum is stretched by the Contraction of the three Muscles which belong to the Malleus and Stapes; which Tension is gradually increased till it finds the single Point or Degree which is harmonical with the external Sound, and then the Hearing is distinct. Hence therefore the Organ of Hearing seems to be twofold, one for admonishing and giving warning, and the other for distinguishing.

§. 563. For by this *Contrivance* ¹ it is possible for an infinite Number of small tremulous Chords to be assigned, of an equal Degree of Tensity in this Lamella, in a Direction from
its

its Basis terminating in its Apex; so that among these almost innumerable Chords there will be always some, which being in harmonical Consent, will tremble with every Sound, so as to be capable of representing the same, and of conveying it as such to the common Sensory; so that the nice Distinction of different Sounds is performed by Means of the Membrane belonging to the Fenestra ovalis, while the Office of the Membrane of the Fenestra rotunda is only to give notice of a Noise or indistinct Sound, the Perception of which being communicated excites the Attention, by which Means at the same Time the bony *Organs*² of Hearing and the Tympanum are stretched by their respective Muscles, that they may be capable of distinguishing what is heard.

¹ They who are versed in the Principles of Geometry will easily understand what is here said. Let us suppose a Circle, in the Center of which is erected a right Line perpendicular to the Plane of the Circle of any given Height; and from the Point or Top of that Line, let a tangent Line be drawn to any Point of the Circumference of the Circle: If this Tangent be moved round the whole Circumference of the Circle, while it remains fixed to the Apex or Top of the perpendicular Line, it will produce or generate a true Cone. From the Apex of such a Cone, let two right Lines be drawn to the two extreme Points of any of its Diameters; and thus will be formed by these Lines an Isosceles Triangle, which will divide the Cone into two equal Parts. But this Triangle will

be divided by that perpendicular Line which we call the Axis of the Cone, into two right-angled Triangles. If now an infinite Number of Lines, parallel to the Basis of the Circle, are drawn from that Axis to either Side of the Triangle, all of them together with the Axis and those Sides will form Triangles which will intercept similar Triangles, and will be constantly the same as to their Angles, in which the parallel Lines intersect the Sides of the largest Triangle, the Apex of which will constantly remain the same. All possible Lengths therefore may be formed betwixt the largest and the least in these Lines parallel to the Basis, even from the greatest (namely, the Radius of the Basis of the Cone) to the smallest, which is but little differing from a Point infinitely minute. What has been before advanced is applicable to the Cochlea, the Septum, or Partition of which (§. 562.) is such a right-angled Triangle; and the small Nerves descending from the Center of the Nucleus or Axis to the Circumference of the spiral Lamina, will be those parallel Lines of which we before spoke. It therefore only remains for an infinite Number of nervous Chords of all Lengths to be formed betwixt the Point or Apex and Semi-diameter of the spiral Lamina of the Cochlea, where it is broadest at its Basis. But thus we shall have an infinite Number of Chords, which may tremble in Unison with the infinite Variety of Sounds; the longest of them will express the most grave Tones, and the shortest the most acute Tones: so that among the infinite Variety, if one Chord will not tremble at a particular Sound, yet another will be found to tremble, harmonically; but when that Chord trembles all the rest which are octaves, fifths, or thirds, greater or less, will also conjoin their Tremors to form one harmonical Sound;

Sound; and thus it will be conveyed to the auditory Nerve, which communicating the same to the Brain produces the Sense of Hearing. From hence therefore the Reason is evident why we are capable of such an exquisite Distinction of Sounds, and also why we do not perceive the greatest Sounds nor the least by the Sense of Hearing; namely, because neither of them can find a consonant Chord in the spiral Lamina of the Cochlea. Thus the largest Pipe in the Organ being blown, yields a Tone hardly perceptible to the Ears. And from hence again it is evident, why half of the Septum of the Cochlea is bony; namely, that the Chords thereto attached might resound; for if musical Chords are fastened to a soft Body, they never yield any Tone.

2 The Organ of Hearing is the most complex of any belonging to the Senses, for it includes, (1.) The external Ear with its Excavations, Eminences, Muscles, &c. (2.) The Meatus Auditorius with its anterior, cartilaginous and posterior bony Part lined with its proper Membrane. (3.) The threefold Membrane of the Tympanum, with the tremulous Chord stretched underneath, which is elastic and nervous, composed of two different Trunks of Nerves like unto the Chords which are stretched under the Parchment of ordinary Drums. (4.) The four small Bones of Hearing, with their four Muscles and Ligaments. (5.) The Cavity of the Tympanum, with its Appendage in the mastoide Process. (6.) The *Eustachian* Tube, with its dilating Muscles and double cartilaginous Gate or Entrance which opens near the Nose. (7.) The Os petrosum, with the Aqueduct of *Fallopian* and hard Part of the Nerve. (8.) The soft auditory Nerve dividing itself into five Branches of small Nerves, two of which are spread

round as many spiral Cavities in the Tympanum, and three are spread within the semicircular Canals. Four of these Nerves terminate at the Fenestra ovalis, and one of them at the Fenestra rotunda. (9.) The Fenestra ovalis and rotunda, with the Vestibulum, Cochlea, and semicircular Canals. With such a wonderful and complex Fabric has Nature formed this Organ, not only to be sensible of any one single Sound, but also that we might perceive all Tones which are Harmonical; and therefore it was necessary for the Ear to be a perfect musical Instrument or Organ; and hence it was necessary for it to be provided with so many small Bones and Muscles, &c. But this Multiplicity of Parts in the Organ of Hearing, renders it difficult for the Physician to determine from what Cause Deafness arises; for the Parts are very numerous, and may be injured various Ways. The external auditory Passage may be obstructed, the Membrane of the Tympanum may ossify or become callous, or it may be broke, the Periosteum of the small Bones may cause them to grow together, the same Bones may be corrupted, the Membrane of the Fenestra rotunda or ovalis may become Callous, the *Eustachian* Tube may be stopp'd up; and, lastly, in the single Labyrinth may happen a thousand Disorders which may destroy the Hearing.

§. 564. But whether or no the extreme Filaments of these small Nerves having performed their Office, and been distributed within the Labyrinth, *return* again to the Brain and common Sensory, is much to be questioned? But thus *Simoncelli* has thought, and so it has been represented by *Mistichelli* in his

his Letters. In short, an infinite Number of Enquiries remain still to be made.

¹ These minute Anatomists proposed a new Discovery with which at first I was wonderfully taken. They affirmed that the soft and hard Part of the auditory Nerve indeed enter'd the auditory Sinus, and were there expanded separately in the Manner which is commonly known; but then, say they, the soft Nerve does not there terminate as is commonly supposed, but returns again to the Brain into which it penetrates very deeply: and therefore is not Hearing performed in the auditory Nerve when it is returned into the Brain, and not in the *Os petrosum*? To this they add, a very considerable Conjecture, namely, that the Senses return to the Brain, by the Communications of the Nerves. But these Anatomists seem to have indulged Conjecture too much, going beyond the Limits of Experience; for no one could ever repeat their Discoveries, which never appeared to me upon the most diligent Enquiry, and which were not supported even by the Discoverer in his latter Epistles. They might have been imposed upon by that small Branch of a Nerve which comes from the Organ of Hearing, and passes into the *Dura Mater* of the Brain; which Communication betwixt the Nerves ought not to seem surprising, since the internal *Periosteum* of the *Os petrosum* is a single Membrane continuous with the *Dura Mater*. But then it ought not from thence to be asserted, that the soft Nerve returns to the Brain after it has entered the *Vestibulum* in the Form of a Pulp; for this seems to be repugnant both to Reason and Experience. The Heart propels the Blood into the Brain with a considerable Force, and distends the same as it were on all Sides in Lines
drawn

drawn from a Center to the Circumference ; and therefore for any Humour to return into the Brain, it must be propelled with a Force capable of overcoming the Resistance of the Blood sent to the Brain from the Heart ; but such a Force can by no means be supposed in a soft Nerve, which is not only a most soft Pulp, but is likewise not provided with any muscular Power in the Ear, whereby any such Force can be communicated.

§. 565. From hence we may be capable of understanding the reason why the Hearing is more acute or quick by applying the Hand *hollow* ¹ to the external Ear, and directing the same towards the sonorous Rays ?

Why, on the contrary, the Hearing is difficult or more dull when the *external Ear* ² is cut off ?

Why the Hearing is more exquisite when the Plane of the Ear is directed towards the Sound at an *Obliquity* ³ of forty-five Degrees ?

And why we hear more plainly when the Mouth is open and the lower Jaw hangs *pendulous* ⁴ ?

Why there is a humming Noise in the Ear, so as to render the Hearing more dull when we *whistle* ⁵ or blow, gape, blow the Nose, speak *shrill* ⁶ or *sing* ⁷ ?

Why deaf People hear the *gnashing* ⁸ of their Teeth, or the Sound of a Body which is held betwixt them ?

And why deaf People likewise frequently hear well by speaking into their *Mouth* ⁹ ?

Why

Why Deafness follows from any kind of Obstruction in the Cavity of the *Eustachian Tube* ¹⁰?

Why Deafness likewise follows from a *Rupture* ¹¹ of the Membrane of the Tympanum?

By what Passage some People are capable of discharging *Smoak* ¹² from their Mouth through their Ears?

Whence it is that we hear but *one* ¹³ distinct Sound not at all confused, though received by two different Ears.

¹ Children in Churches endeavour to move surprise in their Companions, by directing them to apply their hollow Hand to the external Ear, by which means the Sound is conveyed three times stronger than if it was received by the external Auricle only; for the Hand thus receives the Tremors of the Air in the same Manner as the external Ear itself, but in twice as great a Quantity, as it is twice as broad.

² This happens when the external Ear is lost even in Men who before heard the most exquisitely. For when the external Ear is lost, all those sonorous Rays slip on one Side which do not enter the Ear in a right Line from the sonorous Body. But the Surface receiving the sonorous Rays being diminished, and Part of the reflecting Machine being destroyed, the Number of sonorous Rays must consequently be lessened so as to considerably weaken the Sound. For the external Ear, as we observed before, stands out at a Distance from the Sphere of the Head, and collects together the Rays which would otherwise have escaped; and therefore People who are deprived of this collecting Machine must be obliged to direct their Ears
towards

towards every Sound, like Horses and Dogs who have had their Ears cut off, by which means hardly one tenth Part of the Hearing remains; so that in these Animals we may perceive that they move their Head continually towards all Quarters to receive the sonorous Rays, as if they were sensible of their loss of this collecting Machine.

³ Hence it is that People who are deaf do not turn their Face towards the Preacher like other People, but the Side of their Head inclined a little obliquely; for when they look directly towards the Speaker, the convex Face of the Ear being turned towards the sonorous Object, admits much fewer Rays than if they were to be received and collected by the broad and hollow Part of the Ear directed opposite to the Person speaking.

⁴ When a Person is in some Solitude, and perceives a Sound coming from a Distance, which he desires to perceive more distinctly; if we then observe the Endeavours used to hear attentively, we shall find that he stands quite still, holds his Breath and opens his Mouth, because then the Sound penetrates the arched Part of the Palate and *Eustachian* Tube to the internal Ear, almost in as great a Quantity as through the Meatus Auditorius, by which there is almost double the Quantity of sonorous Rays collected. When skilful Painters draw *Apollo* striking the Harp, they express the People Hearing with the greatest Attention of Mind with their Mouths drawn wide open. They might possibly have taken this from having observed the common People giving Audience to a Mountebank, who being full of Credulity stand gaping and with erected Ears to receive what he has to say.

⁵ We are said to blow when we draw in a large Quantity of Air by Inspiration, and retaining the same for a While, and closing the Cavity of the

Nôstrils

Nostrils by the Velum of the Palate as with a Curtain, we then expel all the Air through the Mouth contracted into a narrow Opening, increasing the Celerity of the Air's Current by diminishing the Aperture of the Tube. In this Action therefore the Air being collected and retained, rushes towards the Mouth ; and not finding there an easy Passage, enters the *Eustachian* Tube and internal Ear, so as to press outward the Membrane of the Tympanum, resist Sounds coming through the Meatus auditorius, and occasion us to hear an indistinct buzzing Noise instead of a clear Voice.

⁶ A Person who is used to speak with a grave Voice, endeavours to speak with an acute Tone in order to be heard at a greater Distance, the Tone being then feminine and sharp ; and those who thus use a masculine and strong Voice, when they endeavour to speak with such a shrill and puerile Voice, they do it with some Difficulty of straining. This Shrilness of Voice is formed by a very close Approximation of the Glottis, through which the Air is very swiftly propelled from the Thorax ; and by the same Means likewise the Air rushes through the *Eustachian* Tube into the internal Ear. *Tiberius Gracchus*, who was one of the greatest Orators of his Age, when speaking with the greatest Intensity of Mind to the People, used to cry out like an old Woman, nor did he himself hear in what a disagreeable Manner he spoke ; but to avoid this, he had a Servant who used to sound a Pipe of an acute Tone, to which he rendered his Voice conformable.

⁷ When Persons who are very well skill'd in Music, are desired to sing to any musical Instrument higher, or in a more acute Strain than is natural to their Voice, they easily err when they come to the most acute Tones, nor can they express

press by their greatest Endeavours those Tones which have been set before them by the Organ; and therefore the Ears are disagreeably affected whenever the Voice is strain'd in that Manner: for in the most acute Tones the Glottis is very strictly approximated together, and the Air is very swiftly expelled, both which are Causes of a shrill Voice: but the Air rushing with great Rapidity through the Glottis, enters the *Eustachian* Tube of the internal Ear, so as to disturb the Perception of the external Sound.

* Deaf People who can hear nothing with their Ears, may yet hear by their Mouth. Let a deaf Person hold an iron Rod betwixt his Teeth pendulous, and then upon striking the same he will perceive the Sound of the trembling Iron. There was a certain Musician at a Court, who became deaf by Disease; but by holding the Handle of the Lute in his Mouth, he could then strike the same agreeable to the Rules of Art. It is to be observed, that the Tremors of the Air are like the Returns of elastic or resalient Bodies; but an iron Rod being struck, trembles and communicates its Tremors to the Teeth, so as to shake all the Bones of the Head, and with them likewise the auditory Nerve, as if it was affected by the Tremors of the Air conveyed to the Tympanum. Deaf People are capable of hearing the Discourse of others, while they are carried over the Stones in Coaches or Waggon's which have iron Chains making a rattling Noise; whereas they hear nothing when the Carriage stands still. The Daughter of the great *Colaart* was deaf from her Birth; but yet she could hear and understand, when the whole House was shook by the Report of a Gun. This Virgin was taught to speak by *Ammanus*, and answered to those who asked her, that when she spoke

spoke she perceived something, but could not tell whether that Sense was the same with what we call Hearing. She certainly heard internally, but could not use the Term Hearing in that Sense in which we understand it, since she never heard in that Manner: for they who have never heard are ignorant of what Hearing is, and consequently they are not able to explain that by Words which they know nothing of. But when the *Eustachian* Tube is also obstructed, in that Case deaf People are not able to hear the strongest Sounds.

⁹ I saw a Person who having lost the external Ear, used to receive Sounds by his Mouth; and there are many Instances of this when the auditory Passage is stopped up, or the Membrane of the Tympanum render'd callous; for Sounds coming through the Mouth, are impelled upon the arched Roof of the Palate, and are from thence reflected to the internal Ear through the *Eustachian* Tube.

¹⁰ Upon this I have made some Observations. A venereal Ulcer being seated near these Parts, or Aphthæ being spread round the Fauces occasion Deafness, but not such as is incurable when the Ulcer or Aphthæ are removed. When the *Eustachian* Tube is shut up, the Air retained in the Tympanum, without finding any Vent, is in the mean Time heated and rarified so as to thrust the Membrane of the Tympanum outwards, and press the Membrane of the Fenestra ovalis inwards, by which means the Communication of the Tremors of the external Air to the auditory Nerve is interrupted. This kind of Deafness frequently happens from Quinseys, when there is a Metastasis or Translation of the morbid Matter in a Pleurisy upon these Parts; for Matter or Mucus compresses the *Eustachian* Passage; and hence this kind of Deafness is cured by a Diarrhæa following, by
transla-

ting the Matter another way as *Hippocrates* has observed of old.

¹¹ The *Italian* Philosophers have made many Experiments in this respect by breaking the Membrane of the Tympanum in living Dogs, by which means the Hearing continued for some Time, but gradually lessened, till at length the Animal became quite deaf. For when the Membrane is first destroyed, the Malleus, Incus and Stapes do nevertheless remain in their proper Situations, and are capable of transferring their Tremors to the Fenestra ovalis. But afterwards by degrees the small Bones with their Membranes and Ligaments are dried up by the external Air, contract and become rigid, while the Tympanum is filled with Dust and other small Bodies floating in the Air, which totally destroys the Hearing. Such an Accident I knew in a certain great Prince who stood too near a very great Gun at the Time when it was discharged. But sometimes the Hearing does not totally perish when this Membrane is wounded; for the Membrane of the Tympanum may be easily renewed, and the Wound of it healed, provided the Ears are continually defended from the Injuries of the Air.

¹² If a deaf Patient comes to consult you concerning his Hearing, order him to retain the Air, and make the same Endeavour as if it was to be blown through the Mouth and Nose which are at the same Time shut: If now the Air is blown thro' the Ear, the Disorder is incurable. For the Membrane of the Tympanum sometimes departs from the bony Circle, but this not without Disease, since it naturally adheres very firm. In a Patient who is thus afflicted, the Smoak of Tobacco being received into the Mouth after the Nostrils are closed, it may be blown together with the Air through

through the *Eustachian* Tube, so as to pass out through the external Ear. But in the wild Goat this Fabric or departing of the Membrane of the Tympanum from the bony Ring seems to be natural; since they are not suffocated by stopping their Mouth and Nose, but live by the Air drawn through their Ears. This we are told by *Aristotle*.

¹³ This Question is not easy to solve, nor is it answered by *Valsalva* by saying that the semicircular Canals are of the same Length both in the right and left Ear of the same Person; for who can so much as hope to take an accurate Dimension of these Cavities, seeing the Difference of a Grain of Sand in their Length will here make a considerable Variation. But this Question seems to be the same with that which we proposed with regard to the Eyes, namely, why we see but one Image with two Eyes, when at the same Time the Image of the Object is painted both in the right and in the left Eye, and by them transmitted to the Mind. But this Phænomenon seems to be explicable in the following Manner. So long as the Muscles of the Malleus and Stapes continue perfectly in the same Degree of Tension in each Ear, we then hear but one Sound, both the right and left Ear being then in Unison or Consonance. But even at other Times when I persuade myself that I hear but one Sound, I then hear perhaps a thousand collected into one; for the infinite Number of Bodies which are in harmonical Consent tremble together at every Sound, which is thus increased by new Vibrations, all running together into one whole Tone. When a thousand People sing in a Church, while at the same Time the Organ plays, there are then a great many different Tones produced at the same Time; perhaps there may be eight Tones in the Organ and four among the People; for some Men sing

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Base,

Base, others Tenor, and others Treble ; but the Women sing in Alt. But if now there is only one Person among them all unskilled in Harmony, I then hear all the rest as one Tone, and distinguish the Voice of that one Person as a different and discording Sound. Thus also there are some People who suffer an almost intolerable tingling in their Ears from their own Voice, insomuch that they are obliged to stop their Ears till the Force of the Disorder is over. These People seem to have lost the Consonance, which is necessary in the Organs of Hearing, which cannot all be stretched to Unison ; otherwise this Phænomenon seems to be unexplicable. Concerning Sounds and Harmony *Mersennus* has wrote the best in his very scarce Book, entitled, *Harmonicorum*, lib. 12. Fol. 1648 ; as also in another Volume of Commentaries upon the Book of *Genesis*, in which many different philosophical Experiments are contained ; for that Person being a Divine, endeavoured as much as possible to refer his Writings under sacred Titles. *Kircher* has also published two Books in Folio upon Harmony, the one is *Musurgia Universalis*, printed at Rome, ann. 1650 ; and the other entitled *Phonurgia*, being a Compendium of the Former, ann. 1670.



Of the Internal Senses.

§. 566. **F**ROM all that has been hitherto said (§. 481 to 566.) we learn that our Bodies receive nothing else from sensible Objects to produce Sensation, than a *Change in the Surface* of the Nerve, excited by the Contact of the moving Object.

Seeing

Seeing is the Retina or pulpy Expansion of the optic Nerve touched by a Focus of the Rays of Light. Smelling is the Feeling or Contact of odorous Particles with the Surface of the olfactory Nerve expanded upon the Bones of the internal Nose. Tasting is also that kind of feeling, which is produced from the Contact of sapid Bodies with the Papillæ of the Tongue, arising from the Branches of the ninth Pair of Nerves; and the Touch or Feeling is a Motion excited in the soft subcutaneous Papillæ by some Body rubbing against the Cuticle. And lastly, Hearing is performed when a sonorous Wave or Undulation of the Air makes an Impression upon the auditory Nerve by exciting harmonical Tremors in the Membrane of the Fenestra ovalis. We never hear without Sound, nor see without Light, nor do we even perceive but by some Alteration made in the Body and Organ of Sense. But in the sensitive Organ itself, there is no other Change but that received by the Nerve of each Organ; for Nature has so defended the Nerves in every Part, that it is impossible for the Body which is perceived to penetrate into the perceiving Nerve, or to make any Alteration in the same, but what is received in its Surface. When therefore the Mind perceives any Change in its Ideas or Thoughts, the Body is changed in some of its sensitive Organs; and that Change is made in the Surface of the Nerve belonging to each Organ. So great is the Simplicity of this Contrivance, that it is with Difficulty we can confide in the Truth of it; but this is rather an Argument of its being the Work of infinite Wisdom, which is capable of producing the most complex and intricate Effects by the most simple Means. I do not say that this Change in

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the Nerve is Perception, but I say that we perceive when such a Change is made.

§. 567. This Change in the Surface of the Nerve is produced by the various *Figure* ¹ and Bulk, Hardness and Motion of the sensible Object: whence it seems probable that sensible Bodies, however different, would always excite the same Sense upon the same Organ, provided they were exactly the same in these four *Qualities* ².

¹ If a Dram of Gold is beaten into thin Leaves by the Hammer, there will be nothing in it capable of affecting the Taste; Smelling, or Hearing; but if the same Gold is formed into a sharp-pointed Bodkin, it will wound the Tongue, and excite Pain; or if it is formed into a Bell, it will produce Sound, and affect the Ear, &c. and therefore only by changing the Figure of a Body, which is in its own Nature most simple, its Action or Efficacy may be varied several Ways.

² That is to say, with respect to their Density, Rarity, Magnitude and Minuteness, Hardness and Motion. For these Qualities being changed, the Nature of the Body is also changed with respect to us, so as to make the Body seem to be of another Kind. Every sensible Object which agrees with some other in Figure, Bulk, Hardness and Motion, will excite the same Sensation, and will be taken for the same Body. Gold broke into the most minute Particles, and applied to the Tongue, does not excite any Manner of Taste; but if the same is dissolved in Spirit of Sea Salt, or in Aqua regia, till the Menstruum is saturated, it will continually excite a sweetish and astringent Taste.
The

The Elements or Particles of pure Gold do not excite any Manner of Taste ; but Aqua regia, though not more in Proportion than the thousandth Part in a Drop of common Water, will excite the Taste of a strong Acid. But a Solution of Gold in such a Menstruum has neither the Insipidity of that Metal, nor yet the Acidity of the Aqua regia, but a new and peculiar Kind of astringent Taste. If now a Particle of Silver equally small with a Particle of Gold can be endowed with the same Weight and Density, Hardness and Figure with that of the Particle of Gold, it would certainly be no longer Silver but Gold ; since there would be no Difference, but the same Particle of Silver being dissolved in Aqua regia would afford the same sweetish and astringent Taste with Gold. If I can communicate the same Motion, Figure, Hardness and Density to any small Body which is peculiar to Fire, there is no room to doubt but that Particle or Body will become actual Fire. But it is not in our Power by any Artifice in Chemistry so to change a Body, as to render it capable of pervading Glass without altering its Powers ; and in general, if all Bodies in the Universe had the same Density, Figure, Hardness and Magnitude, they would always communicate the same Sense or Impression to our Organs ; for though they might differ with respect to each other, yet with regard to us they would not be different. Nor is there any other way by which we can distinguish Bodies, but by these four Qualities which we perceive by our Senses. Ask one of the more modern Philosophers, who neglect this Simplicity, what Gold is ; and he will answer, that it is a Metal the most Ponderous, the most Ductile, of a determinate Colour, &c. which are truly the characteristic Marks by which we distinguish Gold

from all other Bodies. But then it is to be observed, that all these Marks belong to the four Heads before-mentioned; for the Weight is discovered by the Balance, &c.

§. 568. But this Change only in the Nerve is not sufficient to produce Sensation; but it is farther required, that the same Change be *propagated*¹ through a free Nerve to some Part in the Medulla of the Brain, and from every *single*² Nerve to a corresponding particular Part in the Medulla of the Brain; and this we learn from Ligatures, Wounds, and Corruptions of the *Nerves*³ and Brain.

¹ It must indeed be owned, that the celebrated Naturalist *Perrault* is of another Opinion; but certain it is, that when the Brain only is at rest in Sleep no Sense arises, even though the same Impression be made upon the sensitive Organ: and therefore a mere Change in the Surface of the Nerve of the sensitive Organ is not alone sufficient to excite Ideas in the Mind; but it is necessary for the Effect of this Change on the Nerve, (I will not say the Change itself) to be propagated into the Brain, so as to produce a like Change in that Part of the Brain where the Nerve terminates, and which receives the Impression. When two Ounces of Water are extravasated into the Ventricles of the Brain, the Patient is not sensible of any thing, not so much even as the Report of the largest Gun nor the strongest Light, nor yet even the most exquisite Pain of burning. Hitherto belongs that wonderful History of the Woman at *Paris*, (§. 284.) who having lost Part of her Scull went about asking Alms with her Brain only covered

vered with soft Integuments. Such a Woman I also saw dwelling in the Village of *Alphen*, in other respects well, only having lost a great Part of the Os bregmatis.

² The Effect of this Change or Impression upon each Nerve is transmitted from thence into corresponding particular Parts of the Medulla of the Brain. If I touch my naked Body with the Fore-finger, there follows a Sensation; and if I touch the same Body with the Fore-finger of the left Hand whilst contained in a Glove, there then arises two very distinct Sensations at one and the same time in my Mind; and therefore it follows, that the Effect of the Impression or Change which arises from the Touch of the right Fore-finger, does not extend to the same Part in the Brain where the Effect of the Change terminates, which arose from the Touch of the left Fore-finger; for if both these Changes were conveyed to one and the same place, they could not by any means excite distinct Sensations in the Mind, but they would be confused together as one. One who duly considers all these Particulars will easily perceive that there must be as many distinct Parts in the Medulla of the Brain, as there are different Senses arising from different Nerves formed into distinct Organs for Sensation; but all these Parts together in the Medulla of the Brain form the common Sensory: for thus do we call that Part in which all the Nerves terminate, and to which they convey the several Changes impressed upon the sensitive Organs. But all the Nerves arise from the Brain, and therefore the common Sensory must be seated in the Brain.

³ If it be asked, What Change is made in the sentient Nerve; I answer, that the Spirits propel forward those which lie next adjacent; and these

again move the next, till the last but one moves the very last; and therefore the Change in the common Sensory can be nothing more than a Repulse of the Spirits against their Origin. This is certainly a very simple Explanation, but we know not of any other.

§. 569. But this Change received in the common Sensory is there so small and so *simple*¹, that nothing can be more so, and therefore by reason of that Simplicity can hardly be traced or explained.

¹ When the Pulp of the optic Nerve receives the Image of an Object, the Mind perceives or sees, and at the same Time distinguishes the Eyes, Nose, Hair, and other Parts of the perceived Image. But what is it that then happens in the Eye? This we are best able to learn by Experiment. If the Bulb of the Eye be taken out of the Orbit without injuring any of its Parts; and if then Part of the Sclerotica be cut off with a most sharp Scalpel from the Back-part of the Globe, removing afterwards the Tunica Choroides and *Ruyschiana*, there then remains the naked optic Nerve expanded into a white pellucid Mucus, which we call the Retina. To this Retina, instead of the Choroides and Sclerotica which have been removed, let a piece of Paper be applied, whose Concavity corresponds to the Convexity of the Eye, and you will then see the Image of that Object painted upon the Paper just as it is before the Cornea; and therefore the optic Nerve in the Act of Vision receives the painted Image of the visible Object. This Image is a proportionable Diminution and Representation of the Rays
coming

coming from an Object in the same Order which they came to the Object. But then how subtle is the Impression of this Image! The Rays of the full Moon collected and thrown upon a Paper by a Convex-glass, make a white luminous Spot in their Focus which is intolerable to the Eye, and yet does not the most sensible Thermometer demonstrate the least Degree of Heat in that Focus greater than the Heat of the nocturnal Air (§. 541.) Again, there is something conveyed through the optic Nerve to the Thalami or Chambers from whence they arise: but that which is conveyed through them, is not the Image which was painted upon the Retina. But if we conceive as many small Fibres in the optic Nerve, as there are minute Points in the Image of the Object painted upon the Retina, it will be evident that nothing more can happen, than that each Fibril must receive some Point of the Image, that is to say, will suffer some Change in its Surface. But this Change in a single Point cannot but be the most Simple, nor can it produce any Thing more in the common Sensory than the slightest Change, or an infinitely small Tremor or Shock. It is a well known Experiment, that if one of the tall Firs used for the Masts of Ships, growing sometimes to the Height of 130 Feet in the Mountains of *Helvetia*, lies down upon the Ground, by applying one Ear to the Extremity of this long Tree, if you then order a Friend to scratch very gently with his Nail at the other End, you will plainly perceive the Noise, though it cannot be discerned by those who stand nearer to its Origin. Thus you see how small a Motion may be propagated to so great a Distance through so hard a Body, which might well appear incredible to a Person who has not experienced the same. But we are
still

still taught something more surprising by *Huygens*. Let a thousand polish'd Ivory Balls be placed in a hollow Tube fifty Feet long; if now the first of these is struck forward, at that very instant of time the last of them will depart from the last but one, while the intermediate ones are at rest. In this Experiment all these intermediate Spherules must have changed their spherical Figure by the Impulse, and recovered it again in so short an Instant of time, except the last, which flew off from the rest, as having no other to resist it. Hence therefore the most hard Bodies in a very small Compass may propagate Motion *ad infinitum*. For since there is no Difference in an Assemblage of a thousand Spherules, there will be likewise no Difference observed in ten thousand of the same Ivory Globules extended in a Line even a Mile long, and also in a Line continued even from the Earth to the Moon; but in a Canal or Tube which is filled with an inelastic Liquor, an Impression will be propagated from one End to the other almost in the same manner; for being received at one End, it will be instantly continued to the other. It matters not therefore, whether the Matter with which the Nerves are filled be elastic or not, or whether they be altogether solid; since it is evident from what has been said, that supposing either of these to be true, the Sensations may be easily and instantly propagated to the Brain.

§. 570. In the mean time different Ideas arise from these Impressions according to the Variety of *Objects*¹, the Difference of the *Nerve*² affected, and the particular Fabric of the sensitive *Organ*³, with the different Part of the Medulla of the *Brain*⁴ from whence
the

the Nerve comes ; as also according to the various *Degrees*⁵ of Motion with which the Objects are applied to or act upon the sensitive Organ : according to all these particular Circumstances, a different *Idea*⁶ is raised and perceived by the sensible Intellect ; and notwithstanding the Idea represents *nothing*⁷ either of the Action of the Object, or Passion of the Organ, yet the same Action of the same Object upon the same Organ is always attended or followed with the same Idea ; so that the Connection of these Ideas follows the Nature or Disposition of the same sensitive Organ, just as if the Idea perceived was the Effect of the Action of some Object upon the same Organ.

¹ Differing with respect to Figure, Magnitude, Density, Hardness, Motion, &c.

² Every Nerve seems to be endowed with a peculiar Faculty, by which it is enabled to perform or exercise the particular Sense for which it is designed. A red Colour has nothing like itself throughout all the things of nature ; nor can it be perceived any other way than by Vision with the Eye. There is therefore a peculiar Faculty in the optic Nerve, by which the Perception of a red or any other Colour may be represented to the Mind : in the auditory Nerve there is an Aptitude to represent Sounds, and in each individual Nerve there is a Power or Disposition peculiar to itself.

³ Where the Nerve perceives it is almost constantly expanded into a Pulp ; not excepting even the Organ of Touch and Taste, as well as Hearing ; but then the Organ placed before the Nerve is various : so that before the optic Nerve is placed

ced the Eye, a dioptrical Machine ; before the auditory Nerve is placed the Ear, a phonergetic Organ ; the Nerves of the Tongue rise up and are received into perpendicular erect Vaginæ. But in other Parts the Sense of Touch or Feeling is performed by a more simple Mechanism. These Laws of Mechanism were prefixed by the Creator to his own Work, which we discover by Observation ; and therefore the Diversity of Senses arises from the Diversity of the Organ placed before the sentient Nerve.

4 It is an Opinion of my own, from which I cannot easily depart, namely, that there are distinct Parts or Provinces in the common Sensory for the different Senses, in the same Manner as we observe a distinct Organ destined to every external Sense. *Eustachius* first plainly demonstrated, that the Origin of the Nerves in the Brain was not confused : but that each Nerve arose from its proper Part of the Brain, by Fibres distinct and separate from the rest of the Nerves. Hence it seems probable, that each Set of Ideas dwell at the Origin of each particular Nerve in the Brain ; those of Sound about the Origin of the auditory Nerves ; those of Light about the optic Nerves, &c.

5 By an intense Light the Eye becomes blinded and painful, instead of being rendered capable of seeing. The very great, swift, and strong Report of a Hand-gun, which has a long and strong Barrel, almost breaks the Membranes of the Ears, the Report being much more dangerous in this respect than that of the low and grave Tone of the largest Cannon ; even there are more than a few Instances of the Membrane of the Tympanum broke by these Sounds. Bodies of too strong a Taste, or being too roughly rubbed upon the Tongue, excite Pain instead of Taste in that Organ ; and the stronger
Odours

Odours excite Sneezing. A Rose strongly pressed against the Nose does not send forth its pleasing Odour; and again, the Tongue which in a healthy State is capable of tasting, perceives nothing but Pain when excoriated, even from the most agreeably tasted Objects. On the contrary, the weakest Sounds do not at all affect the Ear, &c.; so that a determinate Degree of Motion or Force in the sensible Object is required, which it ought not to exceed or fall short of, in order to excite a just Idea in the Mind by acting upon the sensitive Organ.

⁶ In the common Sensory there is no other Change perceived than that of a gentle Pressure; as when we hear, the gentle Tremor of the Membrane of the Tympanum goes and returns.

⁷ When any Sound is published in the Air, the Ears of every Creature are affected thereby. There is not any Person or Creature who does not detest the Noise or Report of a Musket; nor is there any one skilled in Music who is not delighted with the harmonical Conforts. All People therefore perceive almost the same Idea from the same Object. But in such a common Idea there is nothing truly belonging either to the acting Object or the affected Organ; nor do our Ideas arise from a Knowledge of the Figure, Bulk, &c. compared with the Figure, Bulk, &c. of the Object; though these Changes of the sensitive Organ are at present acknowledged by every one to be different from the Ideas which they excite, except *Spinoza* and the *Epicureans*. What Light is, remains a Mystery to every Mortal, and what the Eye is, but few are acquainted with; and yet the Husbandman sees as well as the Philosopher. A knowing Physician who applies a Particle of Sea Salt to his Tongue, perceives not only the saline Taste, but also understands that the dissolved saline Particles penetrate through

through the Pores of the membranous Vaginæ, and velicate the nervous Papillæ of the Tongue; yet he does not taste the Salt in the least better than the most Ignorant. I have seen Philosophers extremely well skilled in the Theory or mathematical Part of Music, who yet were very bad Performers; as, on the other Hand, I have observed excellent Performers whose Heads were made up of nothing more than musical Ears. Sense or Understanding is not therefore the Perception of the Actions of Bodies without us. When we think we see a red Colour or recollect the Idea of the same Colour, we neither think nor see any thing which exists in reality. But if we recollect such an Idea, there is the Representation of coloured Rays to the Mind reflected from some Body, and falling upon the Surface of the Cornea. When we perceive Pain from burning, we do not immediately perceive that which is applied to the Organ; for then any one would believe, that the Nerves sent from the Brain to the Hand were divided by certain solid and most minute small Bodies moved with a great Volocity; but then this is what no Person can know but by much Use and Experience in the Nature of Things, becoming wiser by various Disciplines and Reasonings. But the Idea of Pain which we perceive, neither expresses the Burning nor the Dissolution of the Nerve; for there is only one Intelligence given to the Mind of a present Evil, agreeable to the good Will of the Creator. Sensation therefore is nothing either in the Object, or the Nerve affected; but a certain Idea which God has determined or assigned to each particular Change in the corporeal Sensory. This Doctrine is also acknowledged by Sir *Isaac Newton* in the last Edition of his *Optics*. But we are to observe this by the Way, that by a certain Law

§. 570. *Of the internal Senses.* 239

Law a determinate Idea is raised by a definite Change in the corporeal Organ; so that the same Action of the same Object upon the same Organ duly disposed, always excites the same Idea. Sugar applied to the Surface of a healthy Tongue can raise no other Idea than that of a sweet Taste, and Cloth of a determinate Dye or Surface being exposed to the Sun will raise no other Idea than that of Scarlet. Notwithstanding therefore we perceive nothing of the Object nor of the Organ, yet the Idea raised in the Mind from the same Action upon the same Organ is always alike. You may perhaps object that this Opinion leads us to Pyrronism or Scepticism; for if we do not see the Things themselves nor hear the Sounds by which we are affected, what Knowledge can we have concerning the Truth of any Thing? But this Objection may be solved by a familiar Instance. Suppose yourself to be born in *America*, and never to have heard a Word of *Latin*; if now you hear me speaking in that Language you will certainly perceive no Ideas from my Words, notwithstanding your Ears receive the same Impression with my own, nor will you learn any thing which I teach, or think the same Thoughts which I think, or which yourself would think, if you had learned to speak *Latin*; for in this Case there is no Connection betwixt our Ideas and the Words. An *European* Gentleman in *India* sent six Apples by a Negro Servant to his Friend, with a Letter expressing the Number of them; but the Servant eating three of them by the Way, delivered only as many; the *European*, fond of the Present, asked the Servant why he did not bring the six Apples which were given into his Trust? This was denied by the Negro; but being at length convicted, he acknowledged the Fault, not without great Surprise, that a Piece of
white

white Paper marked with Black should be able to make such a Discovery. The same Thing happens with regard to the Sight: for a skilful Limner takes a Piece of Vitriol, which by mixing together with Galls and Gum Arabick he forms into Ink, and upon a Piece of Paper, which is supplied to the Limner by another Artist, he draws two Men with this Mixture, who are duelling together with the greatest Contention of Body and Mind; but one of these shadowed Men falls down, being run through. All that see this Table, if it is the Work of an Artist, will be moved with Horror, and think of Death, though at the same Time they see nothing but fine Dust disposed in certain Order, all the rest being supplied by the Mind. If a Nose of a particular Figure is drawn upon a Wall, whenever that is seen by a Person, they will think with themselves whose Nose is this. Our Senses therefore teach us an infinite Number of Things which are not existing in Nature without us, and which have nothing in common with the Things themselves. The whole Definition therefore of *Spinoza* must fall to the Ground, by which he calls Sense a Motion of the Mind generated from the Motion of a Body; the Mind being a thinking Part of the Universe, and the moving Body an extended Part of the Universe. All our Sensations therefore are owing to that Disposition of the Mind which was given to it by the Creator, who has so ordered it, as not to be capable of seeing the Object which the Eye sees, and yet that it should form the same Judgment as it would if it had received or collected the luminous Rays themselves. But yet our Senses do not deceive us, for in reality the Rays are reflected and painted in a certain Order upon the Retina. But all our Errors arise from the Hastiness of our Judgment,

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by which we conclude, for Instance, that a red Colour is in the Body itself, because it seems to us to be so. It may be then asked, What is Sensation? In short, we know not. We only know this, that in our Body there are certain Organs adapted to receive certain Motions; and that these Organs being continued into the Brain, the Mind there perceives and judges of the Objects, as if it perceived them immediately itself. But to explain the Connection of all these corporeal Actions with the Mind itself is not within the Power of Man, and much less is it our Business in this Place.

§. 571. The Diversity therefore of our Ideas does not seem to depend only upon the various Manner in which the Extremity of each Nerve is *disposed* ¹ in its proper Organ, but upon a great many other Things, not as Causes, but Conditions assigned by the most wise Creator.

¹ I had formerly many Disputes with my Friend *Raw* upon this Subject; for he was of Opinion, that every Nerve expanded like the Retina in the Bottom of the Eye would be capable of seeing, so that if the auditory Nerve was inserted in the Eye, it would discern Objects by Sight; and, on the other Hand, that if the optic Nerve was inserted into the Ear, and expanded within the Vestibulum under the Membrane of the Fenestra ovalis, it would be capable of hearing. Even he goes further, and thinks that the pulmonary Nerve would be capable of Smelling, if Nature had framed it in the same Manner with the olfactory Nerve. But it does not seem barely sufficient for the Tremors of Objects to be communicated to the Nerves,

but an infinite Number of other Circumstances must necessarily concur, in order for the distinct and respective Ideas to be raised from Objects in the Mind.

§. 572. Ideas thus perceived in the *Mind* ¹ generally excite by their Impressions either Joy or Sadness, or neither of them; so that their Impressions cause either an Indifference, a Love or a Hatred towards the Object by the Action of which the *Idea* ² was excited.

¹ Namely, the Perception or Understanding. This is the simple Knowledge of Things without relation or regard to any other Thing, as, for Instance, a Circle which the Geometrician thinks upon. But generally this Idea or Representation of the Object excites something more than the bare Representation, which is not a simple Idea or Perception, but a Determination of the Will with respect to the Idea. When the Will is desirous of retaining the Idea, the Object is then said to give Pleasure or Joy, there being a perfect Consent or Harmony in the Sensation. If we trace this pleasing Idea to its Cause, we are obliged to love the Object whether we will or no; for we wish that the Thing might remain united to us, nor do we chuse to think rather upon something else; and this we call Love: thus *Mars* sees and covets the Object seen. But when, on the contrary, the Mind is displeased with retaining the Idea, there follows a Sense of Sorrow or Pain, and then it is impossible to think with Pleasure upon the displeasing Object in our Minds, and therefore we desire to remove the sorrowful Object or Cause from its Existence in Nature and in our own Minds, that

that we may not think upon the same ; and this is called Hatred. When I desire an Enemy to be removed, I only request it that I may not think of the Person, which if I obtain I shall be quiet and composed ; for merely from the Idea of that Man, a Sense of Destruction as it were rises in my Mind, which I am obliged to detest. From these two Affections or Inclinations of the Mind all others are derived. The Love of a present Object is Joy, and of a past Object a pleasing Recollection ; and the Love of a future Object is Desire, which we call Hope, when there seems to be a Possibility of obtaining the Thing desired. A present Evil excites Sorrow and Hatred, one that is past excites a Recollection of Anger, and a future Evil excites Fear. The other Affections of the Mind are rather Degrees of Love, according as the Object is either present, past, or future ; or else Degrees of Hatred with respect to something past, present, or to come. All these Affections of the Mind which move us with so much Vehemence, are called by the general Name of Passions of the Mind ; namely, that sensitive or thinking Being, whose Compliance we so often pray for with Tears, and which disturb the Will or Judgment, namely, that Part of the Mind which ought to direct it to the Object. But neither are Passions of the Mind the Result of Reason, nor are they subject to Reason.

Non amo te Volusi, non possum dicere, quare :

Hoc, unum possum dicere, nec amo te.

Et alius Poeta :

———— *Video meliora proboque,*

Deteriora sequor. —————

OVID. in Met. VII.

But even one who understood these Matters better than *Socrates* or *Epietetus* has pronounced, if you see a Woman and lust after her, it is the same thing as if you had committed Adultery with her, *Matth. v. 28.*

² Such an Indifferency is there in the Mind, when it perceives the Idea of a Circle, of a right Line, of the Air, &c. The Senses, both external and internal, are Changes of the Thoughts in the Mind. For Instance: I see a red Colour, and I can think that I see such a Colour present when it is not. The internal Senses differ from the external, not in Thoughts or Ideas, which is common to them all, nor in the Change of the common Sensory, but in the Absence of external Objects; that is to say, when the same Changes of Thoughts or Ideas arise, as if they came from external Objects changing the sensitive Organs, though at the same Time there is no such external Cause present to move the sensitive Organs. For Instance: I see a Negro, and I imagine strongly that I see the same Negro; in this Case the Idea of the recollected and present Object are not at all different. In this indeed they differ, that the Sense is external when the Negro stands present before me, but internal when I represent the same Idea of the Negro to my Mind by Thought. Does it not therefore follow, that both these Sensations are produced in the Mind with this Difference, that the one proceeds from an external Cause, and the other from an internal Cause or Change made in the Sensory itself.

But why has every Age of Man his particular Inclinations? This will appear from reading the Lives of those who have freely followed the Inclination of Nature without any Restraint, as Kings, &c. for such are in the Time of their Youth full of Amours, Liberality and Benevolence; but as
Age

Age advances they become Warriors, and affect a great Name ; and when Age declines they become covetous, and with Avarice they are likewise cruel. So little Influence has Reason upon the Passions, except in those few which alone deserve to be termed happy.

§. 573. But we are so framed, that this Condition of the Mind either of Love or Hatred is apt to excite such *muscular Motions* ¹ in the Body, as may unite the Object of Joy either to the Body or to the Mind ; or by the Efficacy of which Motions the Idea may be so removed, that the Sorrow or Grief which accompanies its Presence shall quite disappear.

¹ All the Muscles are moveable at one and the same Time. In severe Anger we suddenly grow hot, and immediately deliver what we think with Vehemence by the Tongue, which is by *Euripides* called the Servant of Anger. Thus *Achilles* being anger'd at *Agamemnon*, first expresses by his Tongue the Uneasiness, and then threatens by Gesture, when he snatches up his Weapons with his Hand. Nor is there any Delay, but the whole Body is agitated with swift and convulsive Motions ; all which tend to the Destruction of the displeasing Object. For the whole Body is so disposed, that all the Muscles suddenly operate at the strong Idea of a pleasing or displeasing Object which affects the Senses ; by which the former is endeavoured to be retained, and the latter to be removed, as being the Cause of Anger. If a Father sees his Son tumble into the Water, with what a Violence are all his Muscles shook without Design, in order to deliver his beloved Child from the Fate of the

Water. If the Finger is burnt, at that Instant all the Muscles in the Body are convulsed to withdraw it from the Fire. But how come the Muscles to be made thus acquainted with the Danger? No one will pretend to explain this.

§. 574. But since these muscular *Motions* ¹ are excited by Means of the Spirits or Juice of the Nerves, propelled from the Brain into the Muscles; it is therefore evident that the Spirits have a free Course from their Origin in the Brain, from every Point thereof, even to the Muscles which are under the Influence of the Will: Hence it follows, that the common *Sensory* ² is a Part of the Brain, where all these Points are collected together; and that therefore it appears to be in the Medulla of the Brain in the Head.

¹ In all Passions of the Mind there is, 1. A Representation of the Thing placed without us. 2. A concomitant Idea representing the Thing perceived, and exciting the Inclination or Will. 3. A Motion in the Muscles tending to retain the Good, or remove the Evil which is perceived. Hence therefore the Seat of the Passions of the Mind is where the external Object first impresses its Idea; and therefore the Seat of these Passions and of the sentient Mind must be in the common Sensory. Hence all Passions of the Mind are suppressed in a profound Sleep which is free from Dreams; and in an Apoplexy all the Ideas of Joy or Sorrow are obliterated.

² The Sensorium is that Part of the Body where the ultimate Actions of all the Nerves terminate, arising by the several sensitive Organs from Bodies placed

placed without us ; and in which Part the Perception of these Actions is perform'd, so as to determine the Will either to Love or Hatred ; and from whence at length the Influence of the Will first begins, according to its Determination by the sentient Nerves to operate upon certain Muscles, by which the pleasing or displeasing Object is either retained or removed. In this Part therefore the Sensations of all the Nerves terminate ; and here also arises that Power from whence Love and Hatred operate upon the whole Machine, and upon all the Muscles which are subject to the Influence of the Will. This common Sensory seems to be seated where the ultimate lymphatic Arteries in the Cortex of the Brain first unite themselves to, and fill the Beginning of the Nerves with Spirits throughout all the Ventricles and Inequalities of the Brain, &c. Something of the like Kind seems also to have been intended by *Vieussens*, which he calls by the Name of *Centrum ovale*. But the Territories or Limits of this common Sensory seem to be very large and various, so that each Nerve has its particular Part in the Brain where those Ideas dwell which were conveyed by the same ; the Ideas of Odours about the Termination of the olfactory Nerves, of Colours about the ending of the optic Nerves, and of Motion about the Nerves subservient to the voluntary Muscles, &c. In this Part it is that the great Commerce betwixt the Body and the Mind seems to be placed ; as we are likewise taught by Experiments. For if a small Artery be burst in the Ventricles of the Brain in a healthy Person, in the same Manner as a small Artery of the Nose we see burst many hundred Times, in that case some Blood being extravasated into the Cavity of the Ventricles will press upon the arched Origin of the Medulla, whence an Apoplexy follows (§. 284.)

the simple and primitive Ideas of Things are abolished, and the concomitant Affections of the Mind which accompany those Ideas are also suppressed, together with the Motion of the Muscles. This Seat of the Mind therefore is not in the pineal Gland, as *Cartesius* would have it; for who can believe that so many thousand Nerves all destined to different Sensations and Motions can take their Origin from so small a Particle? Nor yet is the Seat of the Mind in the spinal Medulla or in the Cerebellum (§. 600), but only in the arched Medulla which encompasses the Cavity of the Ventricles in the Brain, as *Galen* in some measure rightly imagined, only he erred in believing that the Cavities of the Ventricles were filled with animal Spirits, which we demonstrate to be perpetually moved in close Vessels. And therefore our Humanity or Intellects depend upon the healthy Disposition of this Part of the Brain.

§. 575. The more *distinct* ¹ the Action of the Object is upon the common Sensory, the more distinct and clear will be the Idea thereby produced.

¹ By distinct, we understand here when one simple Object acts at one Time upon the whole common Sensory without being disturbed by any other Object at the same Time; for by that means a simple Thought is produced, and there is but one Perception. For Example: Suppose a Triangle of a red Colour which alone I see illuminated in a dark Place; for then that will be represented most distinctly in all its Parts to the Mind. When I survey any minute Object very accurately with a Microscope, the chief Art consists in placing the Object on a Piece of very black Wood, that so the
Eye

Eye may see nothing more than the Object itself. A Geometrician who is intent upon some difficult Problem thinks upon nothing but upon the Idea of his Problem, which that it may not prove too difficult or disturb his Mind by its Complexity, he divides into separate Parts, and considers each of them alone. Hence those who dedicate themselves to one Study, are usually but half-witted in the rest. No one is better qualified than a melancholy Person for compleating any particular History; for such a one is from a natural Disposition inclined to adhere firmly to one Subject. Even Fools themselves can perceive one Thing or Object as well as those who are in their right Mind; but when Ideas are to be continued in a Chain they fall into Error.

§. 576. The more *vivid* ¹ the Action of the Object upon the common Sensory, the more clear is the Idea thence excited.

¹ This is the second Law of Perception. Such a Triangle as before-mentioned will be difficultly seen in the Dusk of the Evening, but it will be perceived more distinctly if the Light is a little increased, but best of all when illuminated by the Noon Sun. A Person dwelling in the Country and hearing a Rumour at a great Distance, perceives nothing distinct enough, but by attending and stretching his auditory Organs to an harmonical Tension, the Sound becomes by degrees more vivid, and he hears distinctly. Hence in the microscopical Observation of a very minute Object which is to be distinctly examined, it ought to be illuminated with a strong Point of Light, while every thing which surrounds it is perfectly obscure. This is one of the greatest Secrets in these kinds of Experiments sufficiently known to but a few.

§. 577. The oftener the Action of an Object *renewed* upon the common Sensory, the more clear is the Idea.

¹ This is the third Law of Perception. Children are used to get their Task not by thinking only, but by repeating the same Word many Times together with a loud Voice, that from thence may arise an Idea almost indelible; by which Means they are able to read that without Book which they read ten Times within it, which is certainly a very bad Method of learning.

§. 578. Also the more remote the Action of the Object is from all others upon the common Sensory and the more *unusual*¹, the more vivid is the Idea thence expressed.

¹ This is a fourth Law, which any one may experience the Truth of by Experiment; for if you endeavour to recollect what happened in the most early Days of your Youth, registering them down upon a Piece of Paper, you will find that they are Ideas very distinct from all others, unusual, and generally terrible. The Idea of an evil Spirit with Horns vomiting Flame proposed by a Nurse to a petulant Child, a black Dog, a Negro, or the like. We experience, that the Ideas of every Day are effaced by those of the next of the same Kind. *Spinoza* was a melancholy Man, and therefore he died of a pulmonary Consumption, but was not in the least given to Superstition: but he confesses, that when he saw some of the Inhabitants of *Brazil* seven Feet high with yellow hair, such as is wore by that Nation to a great Length; it made so strong an Impression, that he had always
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the same Ideas in his Dreams, and could scarce efface the same in the Day-time by the most strenuous Meditation upon other Subjects. An *Indian* Man who sees an *European* Person for the first Time, every way like himself but of a different Colour, such as he had never seen in Man before, neither will that *European* ever be forgot, nor the Place in which he saw him as long as he lives; so strong and firm is the Impression of Objects, whose Ideas are very different from others.

§. 579. If therefore the Condition impressed upon the common Sensory remains fixed there so *firmly* that it cannot be changed by the supervening Action of other Objects, the present Idea will then remain an inseparable Companion of that Condition in the common Sensory.

• This is made in the common Sensory. That physical Cause which makes the Mind perceive such an Idea without thinking upon any other, is so small an Entity that scarce any Thing can be conceived to be less. Of these same Beings if one exceeds the rest but a small Degree in Strength, then the last only remains present in the Mind, while the rest vanish, which we call Contemplation; namely, when we think some Time attentively upon the Idea perceived, which is the Way to retain the present Idea; for in Proportion as that Impression exceeds in the common Sensory, so much the longer will that Idea remain present in the Mind. This I have experienced by receiving the Focus of a Burning-glass into my Eye; for by that Means the Image of the Sun has been present in my Mind for several Hours. From this Observation Physicians may explain all Disorders

orders of the Imagination. For these Imaginations arise when any impressed Idea is strongly retained and excited by some internal Cause, as may be easily proved by Experiment; for if in a dark Place you turn the right Eye as much as possible towards the left Side, and then gently touch the same Eye with the End of the Finger, you will then perceive the Idea of a considerable Light or great Flame. But in this nothing more was done than changing the Situation of the Retina by transmitting a small Concussion by which there arose a clear Representation of a Flame. The same Thing is experienced, but with more Inconvenience, when the Fist is struck against the Eye, by which means Sparks of Light seem to fly out suddenly from that Organ. But we are assured even to mathematical Certainty, that in so dark a Place there was no Light, and yet it will be almost impossible to persuade yourself from believing that you did not see Light. Certain it is that there was no Cause of the Light seen existing without the Eye, and yet the internal Sense is as vivid as if the Light itself stood before the Eye. If again, such a Cause should produce a like Motion not in the Eye but in the Brain itself near the common Sensory, where the optic Nerve takes its first Origin: I say, if such a Motion be there communicated by the Vibration of an Artery too much distended, there will be the same Idea of Light perceived as before by pressing upon the Retina, even though there is no Light existing without before the Eye. When any one of the small Arteries spread upon the Cavity of the Tympanum has too strong a Pulsation, it excites a Noise hardly distinguishable from that which remains sometimes in our Ears after the Explosion of some very large Cannon. I know at that Time that there is no Cannon exploded, yet I cannot

cannot avoid hearing as it were the same Noise. A black Dog is with respect to my Eye nothing more than a certain invisible Space circumscribed by a Line of a particular Figure, affecting the optic Nerve in a particular Manner; now when this black Dog stands before me, the Cause of that Idea is without; but when the same Cause acts within, I have nevertheless the same Idea as in the former Case: nor will the Idea arising from without differ from that arising from a Change in the Sensory within; and if such an Idea should be strongly rooted in the Sensory, it may remain a long Time, and will not be easily effaced by the Impressions of new Ideas.

§. 580. Or at least the same Idea returns, either in Obedience or contrary to the Will, by Means of some *similar*¹ Cause or similar Idea; which returned Idea being accompanied with a *Consciousness*² of the like Thing formerly perceived is called Memory.

¹ When two things existing together in myself have impressed the Cause of some Idea by operating together and conjunctly, ever after one will revive the Idea of the other, or by recollecting the one the other will also recur to mind. If a Child is sent for the first Time to School, and is severely punished with the Ferula by the Master, and is afterwards educated by the indulgent Parents out of all Danger of Stripes, he will certainly never pass by the School even when he is an old Man without recollecting the Idea of the Stripes which he there received. If Robbers attack a Traveller in a Wood near an old Oak, and put him

him in Danger of his Life, if he should see the same Tree fifty Years afterwards, it will excite in his Mind the whole History, and renew the whole Chain of Ideas which then passed; even so as to make him tremble, though there is not at that Time any just Cause for Fear. If one is at a Loss for some Verse formerly learnt, for Instance, in *Virgil*; if a Friend reads the preceding Verse, you will say that is not it which you want; but upon repeating the first Word of the next, all the rest of the Verse naturally follows in your Mind. I know a Person who had all the *Iliads* of *Homier* by Memory, so that if any one of his Companions repeated a Verse, he could add the following Verses in the same Order as they were to be found in that Author, without the least Reasoning or Hesitation. He had formerly received the Impressions of those Verses in their determinate Order, so that now when one of their Ideas is excited it continually recalls another, and that the next which followed in Succession at the first Impression. If therefore two strong Ideas are impressed at one Time, one will never be recollected without drawing in the other; and this is altogether a surprising Law which the Creator has prefixed to the human Mind.

² Without Conscientiousness it is not properly Memory, but only a simple Recollection like that of Fools; and in general, Men who are of the most happy Memory are the least apt to take in new Counsels or Doctrines.

§. 581. But all this results only from that simple Condition of the common Sensory, which is in Effect nothing more than a *mechanical* ¹ Disposition or Change.

1 All this depends upon the easy Return or Recollection, by which the Mind becomes conscious that it had formerly such Ideas present; and this is Memory, which the Ancients called *Minerva*, or the Mother of *Minerva*. Take away Memory from a Person, and he becomes a mere thinking Machine. If our Humanity was placed altogether in thinking, as *Cartesius* supposes, we should be a metaphysical Point or Atom spontaneously produced, at present thinking and afterwards ceasing to think, without a Continuation of Thoughts. But to our Humanity or Intellect belongs not only Thought, but also the Remembrance of those Thoughts, which we call Memory. The Mind would not understand that it existed the preceding Moment without this Faculty, nor would it know any thing but what existed at the present Moment of Time; but as that Moment is continually vanishing, the Mind would thus know nothing. But since we are thus endowed with Memory, we are capable of retaining and knowing those Things which happened a thousand Years before; for an Astronomer knows that an Eclipse of the Sun will follow ten Ages hereafter, with as much Evidence, and will determine the same with as much Certainty, as we can be assured of an Eclipse that passed ten Ages before recorded in the Almanacks, or which will be seen in the Heavens ten Ages hence by Posterity; nor would there be so much as one Art subsisting among us if the Memory was destroyed. In order to explain this further, we are to observe that Cogitation and Memory are distinct, the former belonging to the Mind, and the latter depending on the Body. They who are furnished with the best Faculty of thinking, publish their Thoughts without any Use or Advantage if they are destitute of Memory. We read of a certain *Spanish* Tragi-
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cal Poet who had wrote some excellent Plays, in which he had pleased himself as the Poets usually do; but the same Poet being afflicted with an acute Disease lost all his Memory, insomuch that he could not remember his Alphabet; so that when he began to recover, he was obliged to learn his Letters, grammatical Rudiments, and Elements of Things over again; which is also reported of an old Grammarian at *Athens*, that he might by degrees recover any Part of his Learning which he had lost. When this Poet was well, they gave him his own Verses which he had composed before his Illness; but he could by no Argument be persuaded that this unknown Work which he so highly praised was performed by himself. At length his Senses being restored to their former Integrity, he composed new Verses, and was with some Difficulty brought to believe, from the Analogy and Genius of the old and the new Drama, that the former was also his own Performance. This Man had certainly a worse Memory than *Pythagoras*, who could recollect that in the *Trojan War* he was *Euphorbus*, and that his Shield which some Ages before was carried by another Man, was hung up in the Temple. Therefore that which is not retained in your Memory is nothing with regard to yourself; so great is the Advantage of this Faculty given us by the Creator.—But this Faculty of Memory, as far as we know, depends upon the Body. Indeed *Socrates* bids us doubt, when he says, that we guess more than we know concerning things to come. In the mean Time if this Law is established, namely, if the Memory results altogether from the Disposition of the Body; in that case if the Thoughts or Ideas are ever so excellent, remove their Connection and it will be Madness. Thus Fools conceive right Notions, or think truly
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of every particular Thing or Object, and are capable of giving a right Answer to a simple Question; but they err in the Connection of their Ideas, their Head running from the Ox to the Ass immediately, without remembering what they thought of before. But this whole Connection of our Ideas results from the mechanical Disposition of the common Sensory, or the first Origin of the Medulla of the Brain; for the Memory may by a mechanical Cause be destroyed for a Time, as for Example, by a Distension of the Veins from drinking too great a Quantity of Wine. When a Person is in a Sleep he is quite destitute of all Memory; and frequently if an Apoplexy is removed without killing the Patient, yet it often deprives the Patient of his Memory during the rest of his Life.

§. 582. Ideas or Thoughts may therefore arise, as well from corporeal Causes within the Body, however latent, affecting the Nerves, Spirits, and Brain, in the same Manner as to excite the same Ideas, as if they arose from external corporeal Causes. And this Disposition is called the primary *Imagination* or *Fancy*.

By this Name we understand the Perception of Ideas arising in the Mind from internal Causes, like those Ideas which are usually produced by external Causes; for when the like unknown mechanical Change is made in the common Sensory, the same Idea is produced in the Mind as if the like Change in the Sensory arose from some external Cause, which is not here supposed to have any Action. This Faculty the Ancients called the *Fancy*, and the Objects of it *Phantasmata* or empty

Appearances. For Example, I see an Object existing without me, a Flame; and this is called Vision, an external Sense, because by the common Consent of all Men this Idea or Vision is raised from an external Object as the Cause. But another Person who presses his Eye with his Finger, will also believe that he sees fiery Sparks, when there is no such real Cause existing without, since other People see no such Thing; and this Idea is represented as strongly and clearly to the Mind when diseased, as if it arose from Fire existing without and placed before the Eyes. The Idea arising from the real Object is referred to the external Sense, and the Perception of that Idea to the primary Imagination. But these Ideas are neither strong nor easily lead the Mind into Error. Sometimes a Cause existing within the Brain, such as extravasated Blood representing red Appearances to the Mind, causes the Idea of a Rainbow as if seen by the Eye; such Rainbows seen in the Beginning of a Fever are usually fatal to the Patient, though he be not as yet in Danger; according to the Observation of *Diemerbroeck*, such a Patient says that he then sees a Rainbow, but you on the contrary see nothing, for there is no Rainbow without the Body to excite such an Idea: the Person may indeed be easily convinced that he is deceived, but then it will be found that the Cause exciting the Idea of a Rainbow is within himself; and that Cause will appear to be as real in the Patient, as the Cause of seeing the Rainbow is real, when the Sun sends forth his Rays which are reflected to us from a watery Cloud.

§. 583. If now there is a strong Remembrance of a similar Idea excited formerly by
the

the Action of some external Object, and at the same Time the present Idea arising from the internal Disposition be vivid, there follows a strong Persuasion in the Mind, that the Cause exciting that Idea is then present without the Body ; and this is called the *secondary* ¹ Imagination.

¹ When the Idea of any Thing in the Mind, for Instance, of a Book, is as strong when the Object is absent as it formerly was when the Object was present, then the Memory supplies the Idea of the Book, and represents it so strongly to the Fancy or perceiving Part of the Mind, that we are almost obliged to believe we actually see the Book placed without us. But this arises from the Representation of the Idea, which is produced by the present Action of an internal Cause with a strong Memory of the same Thing which formerly existed without us. This Imagination often obliges even wise Men easily to err and obstinately to persist in the same Error. I saw a young Man delirious by over-studying himself, who imagined a fierce Dog continually before him ; and the Image of that Beast had so impressed itself upon his Mind that he continually admonished the By-standers to keep away from that dangerous Creature, and could not be persuaded by any Means from believing that the Dog stood at his Feet. But when the Mind not only perceives such an Idea, and believes it to be true, but is also joined by the Will which acts in Consequence according as the pleasing or displeasing Idea is received or rejected ; we usually call such People raving mad. I saw a young Student delirious from a Fever, who believed that he was charged with a certain Number of Pieces of Money,

which he was to deliver to the Militia under the Penalty of a certain Punishment if he did not return to his particular Station and Office: but being negligently guarded, he jumped naked thro' the Window and betook himself to that Station which he imagined to be commanded him; where being found and brought home, he afterwards expired in a little Time.

§. 584. If the Will in the common Sensory, and in the Parts strongly cohering thereto, retains that State which it receives from the Action of a distinct and vivid Object, or if the Action of all other Objects is suppressed or totally effaced, while the former only is retained, this Action of the Mind is called *Attention*¹; by Means of which the Idea is rendered distinct, clear, vivid, and lasting, and is therefore the Parent of *Knowledge*², as being the *best*³ Way to attain it.

¹ Attention is a Continuance of the Imagination, or a Retention of the common Sensory, in the same State in which it was disposed by the Idea which the Will endeavours to retain. Imagination is the Viewing of a stronger Image than others derived from Objects. When the Mind is Intent upon one Idea, all the other Parts of the common Sensory are at rest, and that only is opened where the Idea resides which we would represent to ourselves as present; and this is Attention, which *Cicero* calls hearkening to a Thing. When therefore every Thing is silent and the Action of only one Object is received, then the Perception of that Object is as clear as possible. A Mathematician enquires how, for Instance, a Pentagon may be formed

formed in a Circle; and therefore he rejects all other Ideas and thinks only of the Properties of a Pentagon and Circle, and by that Means easily finds a Way of solving his Problem. Young Men frequently labour under this Defect, namely, that they cannot retain one Idea alone or by itself, without confounding or mixing it with other Ideas of a different Nature.

² *Socrates* and after him *Plato* imagined that the Mind left to itself for a Moment might be able to perceive Things infinite and the most difficult, provided it attended only to the Idea proposed. Thus Geometricians when they think upon any Proposition, as, for Example, the Square of an Hypotheneuse in a right Angle is equal to the Sums of the Sides of a Square, in that case they have the whole Demonstration present before the Mind at one Instant, which is contained in numerous Propositions, and which would take up much Time, and even many Hours, if any one would relate them in Order. Yet are our earthly and mortal Organs invested with that divine Strength, that the Mind can perfectly understand when it drops Images which are confused or weaker than that which it is our Interest to consider. *Franciscus Vieta* a most profound Master in Algebra, and the Restorer of the Analysis of the Ancients, received from the *French* King secret Tables, in which were contained the most private Counsels of the King of *Spain*; but the Writings were found to be in an unknown Character, not legible to any Mortal, and therefore they were delivered to *Vieta* to be expounded. He sets about the most difficult Work, and for the Space of two Days neither eat nor drank, nor saw or heard any Thing, till at length rising up suddenly he found out the whole Mystery: so long a Time was his Mind taken up

without attending to any other Object, that he might find out the one Thing proposed. *Archimedes* went into a Bath when the Problem of *Hierones* was proposed to him concerning the mixed Gold in the Crown, which was suspected to be worked up with Silver by the Artist; of a sudden this great Mathematician observed the Water to rise in the Bath upon his entering into it, and perceived that from this rough and indigested Idea of specific Gravity he could solve the Problem; thus therefore perceiving the Problem solved as it were in a Moment, he jumped out of the Bath with Joy, and ran about naked, crying out, I have found it.

³ It is not impossible for the human Mind to conceive some Object, as, for Instance, a Sphere to be present before the Eyes, and to transpose and examine the same all Manner of Ways, as plainly as if it was present. But this working of the Mind is very laborious, and therefore Mathematicians do not chuse to charge the Memory with difficult Problems, but they draw certain Lines which do not indeed express the Thing itself, before they have prefixed certain Ideas to each Line, and by that Means consider them in Order and in Combination; whereas the Operation would be immensely difficult and laborious if it was to be worked in the Mind without the Assistance of these Lines.

§. 585. From what has been said we have a Knowledge of the five external Senses, as they are commonly counted, together with the internal Senses, as they are called; namely, the Memory, Imagination, or Judgment, Inclination, or Will, and Attention, to which some add *Hunger* ¹ and *Thirst* ².

But

¹ But thus even Pain, Pleasure, Titillation, and other Sensations ought by the same Rule to be reckoned among the Senses when they are only different kinds of feeling, and may be commodiously reduced to Anguish, or Sorrow, or to Pleasure which we call Joy.

² God has given Thirst to Animals, that they might know one of their chief Wants. There is no Necessity to contrive Tortures, for none is more severe than Thirst. *Lyfimachus* being invested by the Enemy gave a Kingdom for a single Cup of Water, crying out, when he drank the costly Draught, so much cost one single Cup. God could not well entrust us to supply our Wants by Reason, for we are led on too slowly by that to those Things which are necessary to be done for us.

§. 586. From hence we are enabled to understand the Reason of many Particulars relating to the Senses, and which may be here proposed as Questions ; such as,

1. Why corporeal *Signs* ¹ having nothing more than the Will of the Creator, do in such a particular Manner, affect, direct, and change our Ideas ?

2. Why it is impossible to *correct* ² or to alter the secondary Imagination by any reasoning, but only by Force or Violence ?

3. Why (*cæteris paribus*) the external and internal Senses are stronger, or more exquisite, when the *voluntary Motions* ³ of the Muscles cease.

4. Why Attention, Memory, and Imagination stupify the *external* ⁴ Senses, and sup-

press the Motions of the Body? And why these Faculties lie neglected or at *rest*⁵ when the other Actions are vigorous?

5. Why the Body grows so very *weak*⁶ when the internal Senses are intensely exercised for a long Time?

6. Whence it is that the frequent *Change*⁷ of the Objects or Subjects of Attention so much exhilarates the Mind?

7. Why *Meat*⁸, Drink, Medicines, *Poisons*⁹, Rest, *Exercise*¹⁰, *Air*¹¹, Heat, Cold, *Custom*¹², and *Passions*¹³ of the Mind have so great an Influence in all these Respects.

8. Upon what State and Condition of the Body depends the *Judgment*¹⁴ affirming or denying, with the *Reason*¹⁵ and regular *Method*¹⁶ of thinking? And lastly, why *Distinction*¹⁷ is of so much Use towards right Reason? And why it so much oppresses the *Memory*¹⁸ or secondary Imagination.

¹ These Signs are apparent in Speech and Reading, for there is no Affinity betwixt the Voice or Word, and the Idea of the Thing which we signify by that Word. If I pronounce the Word Circle, every one immediately understands me, namely, an Idea is raised of a curve Line which I had in my Mind when I pronounced the word Circle; but supposing a Foreigner to be present ignorant of my Language, he will hear the same Sound without understanding the Sense, namely, without the Idea of a Circle following in his Mind. We learn to name our Letters when we are Children by a tedious and repeated Labour, and then to pronounce the Letters, whose force we have learnt, into

into Words, that is, to Read. Thus by degrees these Characters become familiar with us ; so that there is a reciprocal and arbitrary Connection betwixt the Signs and the Sounds with our several Ideas, so that the common Ideas excited in the whole World may be related by us in History, when at the same Time there is no immediate relation either betwixt the Letters or the Sounds with the Things themselves. But this is what has not been granted by God to Brutes ; not even to Apes, which in other respects approach near to us. But this seemed to be a diabolical Invention to the *Indian* Slave, concerning whom I spoke at §. 570. *D. Ammannus*, my much regretted and ever to be lamented Friend, being moved with Compassion towards a Country Lad who was born Deaf, and consequently Dumb, taught him to hear with his Eyes by Signs, by which Means the unfortunate Lad learnt to read and write in the Space of six Weeks Time. He placed the Lad opposite to a Preacher who was explaining the sacred Text, and the Lad fixing his Eyes upon the Mouth of the Preacher, took down the Sermon of which he had not heard a Word, so that he was able to repeat the same at Home. Yet he did not understand what had been said ; only he was taught by observing the Motion of the Face and Mouth in the Preacher, to move his own Organs in the same Manner ; and therefore what he repeated was only mere Imitation without Knowledge. Upon giving this Lad some Bread, he knew by Experience in the Taste what it was, and gave it the Name of Brood or Bread, when at the same Time he was perfectly Ignorant that he published any such Sound, as we know we do when we pronounce the Letters of the Word Brood or Bread. One who attentively considers these Particulars, will wonder at the Connection

Connection of these Organs of the Senses, one of which being affected also affects the other. A Lad who hears well will perceive in the Dark the determinate Voice of a Person producing any Tone, insomuch that the Lad will imitate the like Sounds, and modulate his Voice to the same Tone. But who, I pray, now taught that Lad to make such an infinite Number of the most complex muscular Motions, by which conspiring together the same Sound will be produced which he heard? But even this Faculty is not denied to Brutes, for the Parrot can do the same. If that Bird is suspended in a dark and silent Place while young, and hears the Talk of but one Person, he will learn to imitate the Voice of him that speaks. But how wonderful is this Connection of the Organ of Hearing with the Mouth and Organs of Speech, by which the latter are capable of publishing the same Sounds which are perceived by the Ears? But all these we perform by that wonderful and natural Agreement which unites the external and the internal Senses together: And by the same Means we may explain, why black Points of a determinate Figure may excite the Love, Hatred, or Admiration of another Person; namely, Because determinate Ideas are connected by inseparable Bonds to those external Signs; so that when these Signs affect the external Senses, they excite in the Memory and Mind those Ideas which we judge them to represent.

² It is altogether impossible to overcome the secondary Imagination by the Force of Reason only. Even the wisest of Men often fall into the most false Notions, to which they so firmly adhere, that they cannot be separated from thence, nor convinced of their Absurdity by the most evident mathematical Demonstration. Nor is this any wonder; for all the Force of Reasoning can never persuade

persuade me to believe contrary to the Evidence of my Senses, so as to oblige me to think I do not see, when I see plainly with my Eyes. And this is a Law eternal and sacred from the Creator. If *Pyrrhus* and *Sextus Empiricus* were to rise out of their Graves and by the most subtle Reasonings endeavour to persuade me that I do not see, I should certainly resist them with Incredulity, and firmly adhere to my Senses. For there is an eternal and inseparable Connection betwixt the Impression made on the common Sensory, and the Idea of the Mind arising from that Impression. But as I believe my external Senses, so I am obliged to confide in my Intellects. If a similar and equally vivid Impression should arise in the common Sensory from an internal Cause in the same Manner as is usual from the Action of an external Object, the Mind is then obliged to confide as much in the Imagination, as it used to trust to the Senses. If my common Sensory is so disposed as it was when I saw a red Circle before my Eyes, I shall then absolutely believe that I see such a red Circle. A melancholy Person of the most profound Reasoning, and endowed with the truest Judgment in the Nature of Things, will continue in the Opinion which the Mind conceived, until some violent Motion in the Body makes a stronger Impression upon the common Sensory than the internal Cause of the preconceived Idea, and then he will be set free from his Prejudice. Many surprising Accounts of the Power of Imagination are given us by *Montaigne*, who by Instances proves that the wisest of Persons have some Objects in which they are delirious. I saw an eminent Gentleman who was persuaded his Legs were two Straws; and though he was extremely well skilled in the Nature of all other Things, he could not by
any

any Arguments be persuaded from his Error : his Friends advised him to use his Eyes in the clearest Light, to handle his Legs with his Fingers, and convince himself of their retaining their natural Substance and Figure ; yet he obstinately persisted in his Opinion, being very tender and careful of his Straws, so that he would not stand upon them, lest the brittle Supporters should break. At length his Friends so much fatigued him by their Importunities, that they prevailed upon him to secure his Legs in strong Boots that they might not be broke, and that when he had thus secured them to take a Journey into the Country in a Chariot to relax his Mind : but in the Way were placed two Students, who standing up on one Side of the Chariot masked, and with their drawn Swords in the Habit of Robbers, leaving the other Side of the Chariot at liberty ; the Gentleman perceiving this, forgot his Straw Legs, and betook himself to his Heels, jumping out very nimbly, and from that Time was cured of his Prejudice. From hence many thousands have deplored the Weakness of human Knowledge, since this Gentleman as firmly believed that his Legs were Staws, both to his Sight and Touch, as he now believed that they were real Legs. A Counsellor at *Paris*, to whom the greatest Affairs of the Law were usually referred, retained his Urine from a Fear that he should drown the vast City, insomuch that he would certainly have perished, unless the Physicians had found out a Device to undeceive him. They ordered an Outcry to be made of a great Fire, which there was no hopes of extinguishing ; hereupon the prejudiced Gentleman, to save the People, evacuated three or four Ounces of Urine, and at the same Time was freed from his Error. Another Person was persuaded that he had the Snout of

of an Elephant instead of a Nose, and could not be brought to believe the contrary neither by his Senses of feeling, and seeing himself in a Glass, nor yet by the Reasonings and unanimous Testimony of By-standers; at length a Surgeon made a small Incision in his Nose so as to set it on Bleeding, and easily persuaded him that he had cut off the disagreeable Snout. I knew another Gentleman of Letters who strongly imagined that he carried about with him an uncommon Tumor, from which Prejudice he was freed by a small Wound in the Skin with the shew of a Piece of raw Beef. In the Cure of these People therefore Care should be taken not to oppose them in their prejudiced Opinion by reasoning; for so strong and familiar is the Idea arising from their Error, that you will never be able to convince them; but, on the contrary, they are to be humoured, and their Opinion corrected by some other Device opposite to their Delirium, which will not be otherwise curable. For so soon as you shall be able to excite a stronger Idea in the common Sensory, than that false one with which they are prejudiced, the equable Distribution of Ideas is then restored, and with that the true Judgment of the Mind.

³ If you walk with a Geometrician, and propose a difficult Proposition to him by the Way to be solved; he makes a Sort of Enquiry in his Brain, and you will perceive him stop continually at small Intervals, and afterwards continue on in his Walk when he has resolved the Problem. Thus all the other Passages to the common Sensory are shut up, that the one Thing sought for by the Mind may appear more distinct.

⁴ A Person who is about to meditate or think upon any Matter, does not go into the *Exchange* or other publick Company, but retires into Solitude,

tude, where there may be no sensible Objects to draw off his Mind, and where he may be free from all Motion; for by this Means the Imagination will be the most quick or vivid, and the Memory most ready.

⁵ The deep Study or Extasy in which all the Parts are at rest, is remarkable in the Instance of *Archimedes*. That great Geometrician drewed Cones, Spheres and Cylinders in Sand after the Manner of the Philosophers of his Age; in the mean Time *Marcellus* suddenly overcame and dispersed his Soldiers through the City, where they broke into the Museum of the *Roman* Philosopher with their Swords drawn; but he not at all terrified at the Conquest of his Country, or the present Image of Destruction, commanded the Soldiers not to disturb his Circles. The same *Archimedes* also, upon another Occasion jumped naked out of the Bath, and run about in Public, being seized with a sudden Fit of Joy from his meeting with an Answer to a different Problem, which was proposed to him by the King. This is a common Accident with melancholy People, who usually apply their Thoughts and Senses entirely to one Object, neither rejoicing, fearing, nor hardly thinking about other Things.

⁶ A Mathematician who has been labouring an Hour or two to solve a difficult Problem, will certainly be more wearied and fatigued than a Mechanic who has been working all Day. The Cause is, that in Meditation all the Passages from the common Sensory to the voluntary Motions are shut up, and the Spirits retained in the Brain, so that they cannot flow into the Muscles; and therefore a long Time is necessary to restore those Motions, and to dispose the animal Spirits into their equable Transflux to every Part; and from hence, rather than

than a Loss of the Spirits, arises that Lassitude. Meditating Men hardly perspire, according to *Sanctorius*; and if they do perspire, it is much less than in a Person exercised in walking, or any other mechanical Work.

⁷ This Variation of Objects or Subjects upon which the Mind is employed, I must strongly recommend to you and all who are studious of Learning. The more ardent the Affection of the Mind is towards any Science, the more certainly will the Body be destroyed by Application to it, if you obstinately fix your Study to that one Thing. On the contrary, you may be able to spend a whole Life dedicated to the Muses without fatigue, by mixing other agreeable Labours or Exercises with your Studies. We ought never to let our Minds be strongly fixed for too long a Time upon any one Subject, unless we would become melancholy; but we ought perpetually to alter our Thoughts upon various and opposite Subjects. A Geometrician perceiving any Languor approach, or Love of Solitude, always lays aside his deep Meditations, and falls to Music or the reading of Poetry, which are Subjects of a very different Nature from mathematical Readings. Thus the common Sensory will labour equally in different Provinces, and be diverted by the Variety. But if you desire to persist in one Study, the least Injury that can befall you will be an Incapacity towards the other Functions or Actions of human Life; and though it is certain that you will become learned, and may enlarge the Bounds of the Art to which you apply, yet take care that you do not become a Fool together with your Fellow Citizens.

⁸ It gives me surprise to read the Writings and Discourses of some wise Men, who think that their Thoughts depend upon themselves; for even our
Food

Food only may suppress or obscure that divine Part which is capable of this Faculty. A Geometrician who before Dinner is capable of resolving a most difficult Question, becomes dull, sleepy, and stupid by a large Meal, and the more so if he has drank freely ; since fermented or spirituous Liquors have the same Effect. It is not possible for the Thoughts of a Person to be the same when he is drunk as when he is sober ; and the Ancients have long ago pronounced, that one who drinks Wine will think differently from one who lives contentedly with Water. Even the most wise *Socrates* was for dancing at the Feast of his Scholar *Xenophon*, when he saw a most skilful Harlequin ; but, says *Cicero*, no one danced more soberly or gravely.

9 There are some Poisons discoverable by Experiment, and which have been so improved by the horrid Art of those who have been employed as Poisoners, that any Passion or Faculty of the Mind may be suppressed by its respective Poison, and others excited by some proper Remedy. We are not to look upon the Writings of the Ancients as mere Fables, when we read their Accounts of Philtres. In the Empire of *Indostan*, it is a Practice at Court to quell Seditions by a Drink which the Subjects of the *Mogul* call Poust, made by an Infusion of Opium with the Stramonium : A Portion of this Medicine is swallowed by those who are at the Head of the Conspiracy, without which they are not to have any Dinner ; and thus the Body is indeed not much changed only a little emaciated ; but thus the Principle of our Humanity is suffocated : For the Senses, Perception, Memory, Judgment, and other Faculties of the Mind are gradually effaced, leaving the Body to live as it were a mere vegetable Life, if that may be called living.

living. So ingenious has wicked Ambition made Mankind towards their own Destruction; namely, for fear of a seditious Revolution in the Empire, the new made Emperor usually kills all his younger Brothers, preserving his own Offspring only: But even then he is not safe, for afterwards Princes are produced who are said to have escaped that Fate. But they who proceed with a more cautious Ambition, spare the regal Blood of their Kindred and keep them living; but so stupify or infatuate them by the forementioned poisonous Drink, that if any strong Faction or Tumult is raised, the living Image of a Man is produced to the People, destitute of all Power of thinking.

¹⁰ One who is reasoning cannot walk, but is obliged to sit or stand still, unless he will run the Hazard of falling into Error.

¹¹ The State of the Air has evidently a considerable Influence upon the Faculties of the Mind, according to the different Seasons of the Year, intense Heat or Cold, &c.

¹² Nor is Custom or Use often of less Force.

¹³ These Affections arise from a greater Impression made upon the common Sensory; and which therefore consequently disturb the Thoughts and Use of our Reason.

¹⁴ I do not here ask what Judgment is, to avoid running into a metaphysical Question; but I only enquire what Condition of the Body that is from whence Judgment results. By Judgment, I intend the Formation and Perception of two Ideas at once in the Mind, which makes an Enquiry whether they are the same or different. I ask then whether a Triangle and Circle are of the same Figure? to which every one will answer in the negative; and add, because the Idea or Mode of a Triangle is perceived different from that of a Circle. From

hence I conclude, that Judgment is not an Action of the Will asserting or denying, as it is defined by *Cartesius*. For no Person in his right Mind will say, that two and three make four; or even if he was to say so, it would not be believed by himself. For Judgment is the real Difference betwixt the Similitude or Diversity of Ideas which are raised at the same time in the Mind, and is therefore not a Consequence of any Part in ourselves, but of the mere Ideas only; so that the same Difference or Similitude will oblige the Mind to judge whether it will or no, that one is one and two are two when the same Numbers are present. Perception only determines the Judgment, which will be just when both Ideas appear equally distinct and clear; but wrong when you persuade yourself, that two Ideas are one and the same before they have been distinctly represented. Attention is the only means to rectify this Error, not from its changing the Thoughts but from rendering the Ideas more distinct, namely, by giving a stronger Representation of the thing itself, so that it may be more vivid in the common Sensory at that time than any other Impression. Attention is therefore necessary to form a right Judgment, since that alone renders the Ideas distinct: By Reason we understand the Comparison of Judgments, as Judgment is the Comparison of Ideas. After you have seen that 5^2 and $4^2 + 3^2$ make likewise 25, and then conclude there are therefore $5^2 = 4^2 + 3^2$; then this Conclusion is Reason. But for Reason to be just, the two Ideas ought to be clearly perceived in the Mind; and then the third Idea, with which they are compared, ought likewise to be equally clear; and then we may be capable of concluding in the affirmative or negative without Error, concerning the Agreement or Difference of those

those Ideas : And therefore reasoning appears to be a Complication of Judgment ; and consequently it requires more time than simple Judgment. Hence it is that we find some Men of bad Memory who judge well but reason worse. Fools clearly perceive and judge also distinctly, but they reason wrong ; for that requires a Continuation of many Ideas, which ought to be observed at one and the same time in the Mind, and in this they err.

¹⁵ This is the most perfect in the mathematical Method or Order, that is, when the Principles to be learnt are disposed in such Order, that no Idea is assumed but what has been first expressed before by a clear and adequate Definition ; but a thing can be well defined only when it is clearly perceived. Moreover, from these Definitions are deduced most simple Combinations, concerning which there is not the least room to doubt ; and then these Definitions and primary Combinations having been strictly examined, are assumed as Fundamentals or Principals from whence more obscure and complex Propositions are deduced, which yet contain nothing which is not certain or evident in the preceding. When a Geometrician once in his Life is obliged to believe even against his Inclination, that three Angles of any Triangle are equal to two right Angles, he will always believe it and esteem it as an indubitable Axiom as long as he lives. *Euclid* has given us a notable Instance in his fifteen Books, of the manner in which we may proceed justly, from the most simple Proposition to the Demonstration of the most intricate Theorems.

¹⁶ A Person will not be in danger of Error who does not confound any two simple Ideas. He will become a good Anatomist who considers, that an Artery is of the same Nature in every Part of the Body, but that all the Actions of the Body result from

the Action of the Artery ; which he therefore considers by itself as a simple Proposition, remarking, remembering, and digesting its several Properties, and then using its several known Properties to explain the whole animal Œconomy.

¹⁷ & ¹⁸ Judgment and Reasoning are repugnant to, or refuse a geometrical Method, because it subjects us to one most considerable Impression, namely, a single Notion of a complex Idea ; since the Imagination cannot retain all Notions at once. Passions of the Mind likewise act in the same manner ; for these occasion the Ideas to be represented to us otherwise than they are without us, combining them with some of the strongest Affections in the common Sensory. The Ideas therefore of things are very much altered, according as they are either accompanied with Love, Hatred, or Admiration.



Of Vigilance or Watching.

§. 587. **A** PERSON is said to be *awake* ¹ or watching, whose external and internal Organs of Sense with the Instruments of voluntary Motion, are so disposed that they can easily exercise their accustomed Offices or Motions, and be readily affected by Objects.

¹ Thus we call that State of the Body, in which the Actions of the internal and external Senses and Motions of all the Muscles may be readily or nimbly performed without any Resistance. I am awake when my Eyes being open continually see all Objects, but when I am asleep my Eyes are insensible:

I am

I am awake also when I perceive the least audible Sounds, and when those Sounds escape me I am sleeping. I am awake when by the least Inclination of the Mind or Determination of some external Object my Muscles move, my Tongue speaks, and Feet walk, &c. I am therefore awake so long as that physical Condition continues in the common Sensory, by which the Actions of external Objects being applied in the usual manner to the Organs of the Body, excite the respective Ideas in the Mind. I am also watching when the least Change in the thinking Principle may determine the Principle of Motion towards the Muscles, though the Motion or Act itself cannot be determined. It is provided by a wonderful Institution of the Creator, that one half of our Lives we should be Machines, and the other half cogitative or thinking Beings.

§. 588. Vigilance therefore altogether depends upon the *Presence*¹ of a large Quantity of laudable Spirits in the Brain and its Medulla, with the Nerves and Muscles; and also upon the good Condition of the solid Parts constituting the Brain, Nerves, and Muscles.

¹ That is, when Spirits are duly secerned in the common Sensory, or in the whole Origin of the Medulla from the cortical Part of the Brain, where, after their Separation from the arterial Humours in the Cortex, the secerned Spirits are sent into the Beginning of the hollow medullary Fibres, which are thus equally filled, and through them may be equally conveyed to the five external Organs of Sense, and to the voluntary Muscles. Vigilance therefore in the human Body consists in an equable Repletion in all the Nerves which arise from the Brain.

§. 589. Vigilance may be therefore said to be that State of the Body, in which the Circumstances of the two preceding Sections concur.



Of SLEEP.

§. 590. **B**UT the Knowledge of Sleep was always esteemed to be much more obscure, even though it be only the *opposite*¹ State to *Vigilance*² or Waking; and therefore to acquire a Knowledge of its Nature, it is necessary for us to consider accurately, all the *Phænomena*³ or Appearances with which Sleep is attended; and such are the following:

1. A Person who begins from waking to fall into a Sleep, gradually grows dull, while at the same time all the Senses both *external*⁴ and internal are more difficultly exercised, and being accompanied with a Weight or Heaviness of the whole Body, they at last altogether cease.

2. All the *voluntary*⁵ Motions *begin*⁶ to be retarded by degrees, and afterwards diminished with the Sense of a great Resistance, and at length wholly cease.

3. The Muscles destined to perform those voluntary Actions grow *flaccid*⁷, collapse, become loose and in a manner paralytic, first in the *Eye-lids*⁸, and then in the *Face*⁹, *Neck*¹⁰,
Arms,

Arms ¹¹, and from thence downward, descending *gradually* ¹² through all the lower Limbs.

4. All those corporeal Actions and Passions of the Mind *cease* ¹³, which follow as Consequences of the other three.

5. But in the mean time the Motion of the Arteries, Veins and Heart become *stronger* ¹⁴, *slower* ¹⁴, move equable and full, passing through different degrees of *increase* ¹⁵, according as Sleep itself increases.

6. The Respiration becomes *deeper* ¹⁶, stronger, slower, and more equable by degrees, increasing in proportion as Sleep itself advances.

7. And therefore all the Actions which depend upon these two (§. 5. and 6.) are more *perfectly* ¹⁷ performed; and therefore the Circulation of the Blood is better carried on in order to a due Concoction, *Secretion* ¹⁸, *Perspiration* ¹⁹, and *Distribution* ²⁰ of the Humours with the *Nutrition* ²¹ of the solid Parts; and more especially the Motion of the Humours is *accelerated* ²² through the Blood-vessels which are nearer to the Heart, but slower through the lateral Vessels, and those which are more remote from the Heart, towards which in the time of waking they are propelled by the Contraction of the voluntary Muscles.

8. A Person sleeping *awakes* ²³ when any external Object *violently* ²⁴ affects the Sensory; or from the Sensation of some *Uneasiness* ²⁵

from the Stimulus of any Excrement, or from the Uneasiness arising from the Compressure of any Part, which has been lain upon too long; but sometimes the Person awakes *spontaneously* ²⁶. Lastly, the longer Sleep is continued, so much the more is *Sleepiness* ²⁷ increased, so that (*cæteris paribus*) at length almost the whole Life may be spent in Sleeping.

9. When a Person awakes, he seems to be at first as it were *convulsed* ²⁸, the *Eye-lids* ²⁹ are next opened, the Limbs *stretched* ³⁰, the Person gapes or yawns, looks *drowsy* ³¹, but by degrees becomes fit for Sense and Motion; and then finding his Strength renewed, he is in full Vigour.

Vigilance is when the Body is easily affected by external Objects capable of transmitting their Impressions to the Mind; and, on the other hand, when the Mind by the Will easily influences the Body. On the contrary, Sleep is that State in which no Idea is transmitted from without to the Mind, and the Mind itself exercises little or no influence upon the Body. That is to say, the Creator who has prescribed Laws to the human Species, as well as to other Animals, has placed in our Bodies, as well as in Brutes, a twofold Machine, one of which continues to act until the whole is destroyed; that is to say, 1. The Heart and Organs of Respiration so far as these last conduce to Life; to which add the peristaltic Motion of the Intestines, and all those Motions which derive their origin from the Systole and Diastrale of the Heart. When these Machines are at rest, the Body is perfectly dead, so that it can never be raised again in this World. The other Machine in the Body is the animal Part, which

which acts and rests alternately at times. By reason of this vicissitude in the animal Part it is that Man is no more than a mere Machine during a considerable portion of his Life, namely, in the time of Sleep, at which time the animal Part is dead, and the formal vital Machine only continues to act; but if that also ceases, a fatal Sleep ensues, from which we never awake, namely, perfect Death itself. These two kinds of Death are wisely called Sisters by *Homer*, and by *Gorgias Leontinus* the Orator; for Sleep and Death differ only as to Time or Extension. Sleep is the Death of the Brain continuing for a short time, while in the Interim the Cerebellum continues vigilant and active; but when the Cerebellum also sleeps, or ceases from Action, it produces a perfect Death of the whole Animal.

² This is a state of the common Sensory, in which, with respect to the Solids, the Nerves in their Origin readily receive their spirituous Fluid or Juice, and easily permit the same to pass through. But with respect to the Fluid itself, Vigilance may be said to consist in a ready and plentiful Flux of the Nervous Juice secreted from the Blood of the carotide and vertebral Arteries, sent into the Origin of the Medulla and Nerves so plentifully and freely, as to be most fit for Motion, to be easily determined according to the Variety of external and internal Impressions. On the other hand, Sleep with respect to the Solids consists in a Compression or collapsing of the smaller Vessels of the Brain, so that they are not able to transmit their Juices; but with respect to the Fluids, Sleep follows when the Matter or Humours forming Spirits do not flow to the cortical Part of the Brain, or when the same Spirits are not there separated, or else when they are not continually sent into the beginning of the Medulla.

I have

3 I have frequently spent whole Hours in observing the appearances of Sleep in Children and innocent People, and have by that means accurately remarked all the Changes by which they fall into a Sleep from being awake.

4 A person who is sleepy, but not yet fallen into a Sleep, has his Hearing, Sight, and other Senses more dull, next the Attention ceases; afterwards the Memory and other Passions of the Mind become weak, the Thoughts and Reasoning are interrupted or confused from what they were before; so that the Ideas are confused, and by degrees their Connection broke.

5 The first degree of Sleep beginning is, that we yet remain conscious that we are going to Sleep; for Sleep itself, as some of the Antients have well observed, takes hold of those who fly from it, and flies from those who follow it; for no Person ever observed in himself in what manner he began to sleep.

6 People think they are doing nothing when they sit still, when at the same time they labour incredibly hard. But this Opinion arises from use. Musicians who have nothing more before them than sixteen Notes or Marks upon the Lines of Music, are by them only determined to each Key; after which their expert Fingers move with so great a Velocity that they do not mistake one Note, nor yet do they know that they agitate such an infinite number of Muscles. For all the Muscles of the Back, namely, the Sacrolumbales longissimi, Semispinales, and others of the like kind, are employed in erecting the Body. Nor is the Head sustained but by the Action of many Muscles, which ceasing at the time of Sleep, the Head inclines forward. The same is also true with respect to the lower Jaw. Therefore the second degree of Sleep is

is an insuperable Resistance of the Muscles, which obstinately refuse to continue their Action ; so that the Eye-lid, for instance, cannot be sustained by the strongest influence of the Will, though in the Time of waking it was moved without the least Sense ; also the weight of the Head and lower Jaw seems great to a Person who is inclined to Sleep, though it be not at all perceived at the time of Vigilance. In Sleep therefore the animal Spirits seem to be rendered unfit for Motion in the common Sensory.

7 They become flaccid, paralytic, or immovable ; in which they differ from a Cramp or Tetanos which is joined with a Rigidity. Such a flaccidity of the muscles is a most certain sign of Sleep.

8 This is a wonderful providence, since no part of the Body is more in danger during Sleep than the Eye, which is required to be perfectly clear and transparent. Nature has therefore placed a safe guard to the Eye-lids, namely, an orbicular Muscle, and has so formed the Eye that we cannot be able to go to Sleep till the Lids are closed. And therefore not all the Muscles in the Body are relaxed at the time of Sleep ; for the Sphincters then act the most strongly, that is to say, the Sphincters of the Eye-lids, Mouth, Bladder, and Rectum are contracted in the time of Sleep.

9 Infants inclining to Sleep, begin first to nod, the Muscles of their Face become lax or plain, the Lips and Cheeks subside as in Death, and the lower Jaw falls down ; and from these signs only one may easily know that a Man is inclining to Sleep.

10 I have frequently observed People falling asleep in some public Place, as for instance, at Church, where the Eyes first wink, and then the
Head

Head nods; at which awaking, they rise up a little amazed, and hold their Head steady; but it is not long before they let it slip again, Sleep stealing on so that the Muscles cannot sustain the Head, because they are relaxed; but all of them are not relaxed at once, because the Head inclines this way or that according as the Muscles on this or the other side happened to be less paralytic than the rest, so as to draw the Head to their side. Nor is it long before the Muscles of the Neck are also relaxed, whence the Head is inclined forward; and this is a Stage differing from the former. Nor is the Will capable of resisting the force of Sleep, as Soldiers know by sad experience when they are not capable of shaking off Sleep while the Enemy watchfully surrounds them, even tho' they know that they purchase this pleasure at the expence of their Life. All this irresistible Power of Sleep is very well expressed by *Virgil*:

*Jamque fore mediam cæli vox humida metam
Contigerat, placida laxarant membra quiete
Sub remis fusi dura per sedilia, nautæ;
Cum levis ætheriis delapsus somnus ab astris
Aera dimovit tenebrosam & dispulit umbras,
————— fuditque has ore loquelas:
Aquatæ spirant auræ, datur hora quieti;
Pone caput, festosque oculos furare labori.
Ecce Deus ramum, Lethæo rorè madentem,
Vique soporatum stygia super utraque quassat
Tempora: cunctantique natantia lumina solvit.
Vix primos inopina quies laxaverat artus,
Et super incumbens, cum puppis parte revulsa,
Cumque gubernaclo, liquidas projecit in undas
Præcipitem, ac socios nequidquam sæpe vocantem.*

¹¹ So that no one can sleep with their Body erect, for the Column of the Spina dorsi is held strait by the conjunct Action of an infinite number of Muscles, the power of which being absent, the whole Trunk collapses. And soon after, if such a Person who is about sleeping endeavours to stand upright, he will accordingly tumble down upon the Floor.

¹² They who write while they are awake, as they fall asleep perceive the Pen slipping out of their Hand. Cranes are said to keep a watch to guard against any Alarm, that is, one of the Flock stands upon one Leg holding a Stone in the other, so that the Stone falls and keeps the Watch-bird awake so soon as he begins to sleep. When the Muscles act they are hard and turgid; and such will be the state of the Muscles of the Hand, while it grasps a Stone; but those Muscles grow flaccid and soft, when the Person is about to sleep and let the Stone fall.

¹³ This State of the Brain is the same as in the Man at *Paris* mentioned before (§. 284.) who had his Dura Mater naked; for when any one giving a Stipend compressed the Brain of this Man, he began to grow sleepy, insomuch that the Sleep became profound when the Pressure was gradually increased. But here we speak of that perfect Sleep which is the image of Death, in which therefore there is a cause impeding the Spirits from flowing into the Nerves, whether that be a consequence of a Paucity of Spirits, a Stagnation of them, or an Inaptitude to Motion.

¹⁴ For the strength of the Pulse increases in Sleep, though it becomes slower in number: for if you count the Number of Pulses in a Child while waking, and compare that number with the Pulses made in the like space of time during Sleep, they

they will be found fewer in Sleep, but more equable, full and strong; and from this sign only you may know that a Child is sleeping in the Cradle, even though you use no other Sense. In a Phrenzy, when a Patient begins to incline to Sleep, one may be able to judge of the Force of the disorder by the Pulse; for when the Pulse is larger, stronger and slower than in the time of waking, the Sleep will be serviceable; but if the Pulse is quicker and weaker, the Sleep will be but short and of no service.

¹⁵ The most profound Sleep is a perfect Apoplexy, in which the Pulse is usually exceeding strong, insomuch that the Vital Powers appear stronger a little before Death in an apoplectic Patient, than they were ever observed in the same Person in Health. At the same time they are hot, look red, and sweat all over, the more as the Sleep is profounder. In an Apoplexy therefore, and in Sleep, the Force of the Heart, Arteries and Veins is increased.

¹⁶ A sleepy Person may be easily known from the manner of his breathing; for he breathes more deep and slow with a kind of audible Sound; whereas we do not hear the breathing of a Person who is awake, as we do in Sleep from the strong Depression of the Diaphragm and Elevation of the Ribs. Hence in Sleep the Perspiration seems to be most perfectly carried on; but when the same is increased, it becomes audible, and produces a kind of Snoring like that which the Bronchia yield in a fatal Apoplexy, and which is a certain sign of Death. But even a most profound Sleep is nearly related to an Apoplexy.

¹⁷ All the vital Functions are stronger in a Person who is sleeping, and are more perfectly exercised, namely, the Concoction of the Stomach, the peristaltic

peristaltic Motion of the Intestines, the Secretion of the intestinal Juice, of the Bile and pancreatic Juice, with Alterations of the Blood in the Lungs, Heart and Arteries, the several Secretions and Assimilations, which are all better performed in Sleep than in Vigilance. All the Vessels are therefore well disposed, except those which are subservient to the animal Faculties and Functions, while those which depend upon the Equability of the Circulation are better performed in Sleep, excepting the Functions of the Brain and Nerves.

¹⁸ The Separation of one Liquor from another, and the Secretion of dissimilar Parts from the homogeneous Blood.

¹⁹ When the Humours are most equally distributed and applied to all the Vessels in the human Body.

²⁰ This Distribution proceeds from the Arteries, whose Motion depends always upon the equable Force of the Heart; but the Equability of that Force is often interrupted by the Muscles; and therefore it becomes more agreeable when they are at Rest.

²¹ Nutrition first requires a Preparation of the nutritious Matter, and afterwards a Distribution of it when prepared, that it might be applied to the solid Parts and firmly adhere to them. All these Circumstances are best executed in time of Sleep, which therefore restores the Limbs which had been fatigued with daily Labour.

²² In a Person who is sleeping many Actions cease, and yet the greatest Heat is diffused throughout the Body; for every Person is warm while sleeping, even though they were cold when they first composed themselves to sleep. But yet I do not affirm that all the Humours are moved more strongly than in the time of Vigilance; but I here
speak

Speak with regard to the Vessels and Humours of the first kind, and of the Motion of the latter into the small lateral Vessels. But with respect to the Humours which are transferred from the Arteries into the Veins, they are accumulated in these last, and not urged forward by the Action of any of the Muscles towards the Heart. Hence the Body is by Rest filled with Humours stagnating in their Vessels. In a word, the Motion of the Humours in the first Series of Vessels, that is, in the sanguiferous Arteries and Veins, with their Appendages, the Sinus's and Auricles, is more accelerated during the time of Sleep than Vigilance; but in the serous Vessels, the Lymphatics and Nerves, the Circulation is little or nothing at that time. But the Heat of the Body is increased by the Attrition of the Humours augmented in the large Vessels; for this Attrition is the sole Cause of animal Heat; and the Heat of the Body is diminished in proportion to the Loss or Consumption of the red Blood. Hence therefore the Blood only is accelerated during the time of Sleep, while the rest of the Humours circulate more slowly than when a Person is awake.

²³ A Person awakes by a Commotion excited in the common Sensory, which was before at rest; whether that Commotion is excited by an external or an internal Cause.

²⁴ When an intense Light illuminates the Eye, or when a great Noise affects the Ear, or the like Impression powerfully moves our Senses. Sleep therefore terminates when the external Senses begin to perform their proper Offices; and this happens when the external Nerves are powerfully irritated by the Objects; and by that means strongly press back the Spirits in the Nerves towards the common Sensory.

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²⁵ The general Cause of our awaking is that some Part of the Body (for Instance, the Back or Side which has been lain upon for six Hours) is half inflamed, from whence an uneasy Sense arises. Otherwise the Stimulus of discharging the intestinal Fæces, or evacuating the Bladder, or else of spitting freely to clear the Lungs, or by a sneezing which expels the Humours of the Nostrils.

²⁶ It is commonly believed that we awake naturally only from Custom or Use, because the Spirits are recruited within a definite time, so as to distend the nervous Tubes. But I much doubt whether the Mind ever awakes spontaneously of itself; I say spontaneously, while the Mind continues in the same Disposition in the Body as it was while asleep, the Sleep ending without any new Action excited in the Mind; and therefore I doubt whether a Person awakes merely from the renewed Quantity of Spirits without any external Cause or other Stimulus. I have made some surprising Experiments with regard to this both in myself and in other Animals. The more a Person sleeps, the greater is the Inclination to sleeping. One who sleeps but a single Hour beyond his usual time, will be sleepy all that Day. A very rich Youth who went from *Leyden* to take up his Title of Nobility, having over-drunk himself, was ordered by the Prince to be carried from the rest of the Courtiers into a silent and dark Place, where he slept three Days and three Nights; for whenever he awoke, believing it to be the middle of the Night, he returned to sleep again. I say a certain Physician of some Learning, who took a wonderful Delight in sleeping: he by retiring into a dark and silent Place slept so perpetually, that having lost his Intellectuals, he perished stupid in an Hospital. This unfortunate Gentleman was captivated with an

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Opinion

Opinion that Sleep was useful to him, and therefore passed many Days in Sleep; but when he was awaked the first time by his Friends, it was evident he had lost much of his Learning; and by repeating again his profuse Sleeping, he became at length quite stupid.

²⁷ Namely, an Animal placed in a dark Room where there is no Light nor the least Noise, has been observed to sleep perpetually. Many Animals sleep the whole winter. Weasels of various kinds, Foxes and Beavers betake themselves to Sleep at the Approach of the Winter's Cold; and thus they continue till they awake in the Spring. Many Particulars have been collected by *Fortunius Licetus* with regard to this, in his Treatise of animals which live a long time without Food or Air. Dogs well fed and using no Exercise, sleep quietly almost Day and Night.

²⁸ A Dog or any Person of our own Species being suddenly awaked, is always in a manner convulsed by the sudden Influx of the Spirits into the Muscles, which continue relaxed during the whole time of Sleep; by which means they are suddenly obliged to contract.

²⁹ As the Eye-lids are the first which collapse or become paralytic, so are they the first of the Organs which are excited or moved upon waking.

³⁰ Not only Man but the most active Animals, such as the Lion, Tyger, and Leopard who sleep in Dens, stretch all their Limbs as soon as they awake, and then recover their former Strength. By this means the Spirits seem to be restored to their free and equable Course through the Nerves of the Limbs.

³¹ The Vigour of the Senses does not return altogether and at once; for even the strongest Animals are much weaker by long watching, and may be

be easily overpowered in their first Endeavours to rise up from Sleep.—From this whole History it is evident, that to recover a Person from Sleep to Vigilance, it is necessary for that Impression which is conveyed through the sensitive and motive Nerves to pass to the Sensory, and restore the Vigour of the voluntary Muscles, and remove Sleep. Sleep is therefore a Rest of the animal Faculties, or of the Instruments belonging to Sense and Motion.

§. 591. Sleep is occasioned, promoted, and increased in us,

1. By Eating too plentifully of the more *solid*¹ tough Aliments, which remain a long time in the Stomach.

2. By Drinking plentifully of vegetable fermented Liquors, which are the more somniferous in proportion as they abound with inflammable *Spirits*².

3. By the Use of *Spices*³, which are very penetrating, fragrant and spirituous; to which add Saffron, *Clary*⁴, Sage, and the like, which yet are free from any injurious Acrimony.

4. By the milky Juice of Poppies, the viscid Juice of Hounds-tongue, and the Juice of wild *Lettuce*⁵, *Mandrake-apples*⁶, or the Juice of *Nightshade*⁷.

5. By *Weariness*⁸ from violent Labour sustained for a long time.

6. By a most *quiet*⁹ Disposition of Mind, while at the same time the Body is perfectly at rest, and unaffected by the Action of any sensible Object.

7. By Excess of *Heat* ¹⁰ or *Cold* ¹¹ too much increased, whether proceeding from some common Cause, or from the particular Temperature or *Age* ¹² of the person.

8. By all such Causes as hinder the *Protrusion* ¹³ of the vital Blood into the cortical Part of the Brain, impede the Course of the same through its Vessels in that Part, and consequently obstruct the necessary *Secretion* ¹⁴ of the Spirits thence depending, with the Derivation of them into the Nerves, Organs of Sense, and voluntary Muscles; and also impeding the *Return* ¹⁵ of those Spirits from these several Parts towards the common Sensory: hence it may be from too profuse *Evacuations* ¹⁶, a *phlegmatic* ¹⁷ Disposition of the Humours, or too much *Fat* ¹⁸ urging the Humours inward, a Plethora compressing the smallest Vessels, *Wounds* ¹⁹ of the Brain, an *Inflammation* ²⁰ of it or Abscess there formed, an Extravasation of Humours under the Cranium of the Brain, a *Compressure* ²¹ thereof, the *Loss of Substance* ²², a Putrefaction; and many Accidents of the like nature, which if they do not injure the *Cerebellum* ²³, produce Sleepiness and Stupidity without interrupting the vital Functions.

1 If the Stomach is filled with Flesh-broth, you will not sleep; but if instead of that it is filled with Beef, it will render a Person perfectly sleepy. And this is said to arise from the Pressure of the distended Stomach upon the descending Aorta; but it may possibly be from the Aliments more strongly affecting the nervous Papillæ of the Organ,

gan, so as to cause a Derivation of the Blood or Spirits from the Head or animal Organs towards the natural or chylopoietic Viscera; whence the former will be weak, and the latter more strong and inclined to Action.

² Among all things which excite a fatal Sleepiness, that may be most certainly produced by Spirit of Wine, which if drank in too large a Quantity, produces sudden Death, as I once observed in this City in a Man who made Experiment how much he could bear, but in six Hours time was taken off with an Apoplexy. There is not any kind of Drink which inebriates, but in proportion to the Quantity of inflammable Spirit which it contains; and the sooner do liquors fuddle, as they contain more of this Spirit. But the greatest Degree of Drunkenness always produces a most profound Sleep, a Snoring, and an Apoplexy itself. Thus *Hippocrates* has formerly observed, in the fifth Aphorism of his fifth Section, that those who lose their Speech and lie without Motion in Drunkenness, die of an Apoplexy within three Days time, unless they recover their Voice within that Space, in which a Crapsula usually terminates; namely, within twenty-four Hours, or else they will be taken with a Fever.

³ Among the Effects of Spices the most considerable is a Pungency and Bitterness, by which they heat the Tongue. But there is scarce any of them more bitter and warm than the purest Opium which has been lately brought in Tears from *Ægypt*, which is the true Juice distilling from Incisions in the Poppy-heads, so greatly in request by almost all the *Eastern Nations* or *Asiatics*, and so sharp upon the Tongue that it excites almost an intolerable Heat; and being applied to the Skin like a Plaister raises a Blister. This warm or spicy Opium therefore and such like Substances excite

Sleep. I have been told by Druggists and Grocers, that when they have received large Parcels of strong Aromatics lately arrived from *Asia*, such as Camphire, Saffron, or the like, that upon suddenly opening them both themselves and Servants have been invaded with an almost insuperable Sleepiness. When new Wines are racked off from one Cask into the other in a Vault, all the Workmen become sleepy, merely from the Vapours. There are therefore different Causes of Sleep, besides those which are commonly known; for these spiritous Substances all excite Sleepiness.

4 A Person will be sleepy after walking amongst Clary; and the same will be also found true after walking amongst Bean-flowers; in short, a Person who takes a Nap in the midst of a Bean-field will become stupid.

5 Namely, the wild Lettuce, having the virulent Smell of Opium, according to *Baubine* (*odore opii viroso*, *X. B.*). We read that Botanists have observed that people have been killed by eating Lettuce in the hot Season of the Year in *Italy*. But this fatal Consequence does not arise from the common Lettuce of our Gardens, but from that *Italian* sort, which being broke transfuses a Juice like Milk, white, and smelling strong like the Juice of Poppies; and which Juice being taken in great Quantities, together with the Plant itself, produces exactly the same Effects with Opium.

6 There are many who deny Mandrake-apples to have this power, and there are some who have swallowed those Apples publicly; yet the generality of Writers enumerate them among the Tribe of Narcotics. However a certain Professor at *Paris* eat one of those Apples in the public Chair without any Detriment.

7 More especially the Solanum or Nightshade of the Shops.

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⁸ From Weariness follows the most profound Sleep, even much resembling Death itself. I have known some so much fatigued with Labour and long Watching, that they have fallen asleep by the Sides of Mortars, from whence they fling Bombs in the besieging of Cities; nor has the horrid Noise of the breaking of the Shell disturbed them. I knew a certain Gentleman, otherwise not much addicted to Sleep, who taking a long Journey on Foot, and being much fatigued with the Summer Heats, slept so profoundly that he did not hear the breaking open of his Chamber-door, nor the tumultuous Noise of People in his Chamber. Soldiers being wearied out by Day and Night in the besieging of Cities, learn to sleep by the Sides of the Mortars, from whence are thrown Iron Shells full of combustible Matter.

⁹ This has been well expressed after *Homer* by *Ovid* in elegant Verse (*Metamorph.* II.). Certain it is that when a Man in Health is placed where none of the Senses can be affected, where no Light can be seen, or any Noise heard, no Uneasiness to irritate the Body, nor any Care, Reasonings, or Reflections to disturb the Mind; that Man will soon fall into a Sleep whether before or after Dinner; or even though he slept the whole Night before, provided no Object or Motion of the Body excites the Spirits. I have seen Philosophers in the deepest Meditations fall into a Sleep, unless the falling of the Book in which they were reading excited the Spirits to Motion.

¹⁰ Almost every body is inclined to sleep in the Noon Heats of the sultry Dog-days.

¹¹ There is not any kind of Sleep more fatal, than that which proceeds from intense Cold; and in this manner I had like to have slept in the Year 1709, going in company with a Surgeon in a Coach to see a Lady who had broke her Leg at a

Place two Miles distant from *Leyden*, the Winter being extremely severe. For both myself, the Surgeon and Coachman were seized with such a Sleepiness, accompanied with such an inexpressible Pleasure, that they would certainly have fallen Victims to the fatal Pleasure, if I had not been aware of the Danger, and advised my Companions to get out of the Coach and stir their Blood by walking ; by which means the Sleepiness was shook off, and every one came to himself. They who walk through the Snows in the most severe Cold, are taken with an almost insuperable Propensity to sleep ; but if they give way to the fallacious Inclination, they will sleep a perpetual Night without ever waking again.

¹² Old People, whose Heat is almost entirely exhausted, are continually sleeping ; and at length sleep into Death. On the contrary, a most intense Fear produces a *Carus*, and Sleep which is no less fatal.

¹³ The excellent Anatomist *Drelincourt* having tied down a most fierce Dog upon his Back, uncovered the Carotid on each side, and fixed a Ligature upon each, whence the Animal continually staggered, and fell into a most profound Sleep ; but when the Ligatures were taken off, the Animal returned to his former State of Vigilance : it therefore follows, that the intercepting the Course of Blood to the Brain causes Sleep ; and it is remarkable that the Experiment succeeds, though the vertebral Arteries are not at all compressed by Ligature.

¹⁴ Every Cause which compresses the cortical Part of the Brain, the Impetus extending to the Medulla, infallibly produces an Apoplexy. In the most ardent Fevers the Patients are watchful at the Beginning of the Disease, and as the Disease

Disease advances they become delirious, which Delirium being increased they become raving with perpetual Vigils, and at length perish with a Carus or Apoplexy; namely, a continual Sleep joined with a most acute Fever.

¹⁵ When all the Nerves are at rest, Sleep easily follows.

¹⁶ Too profuse Evacuations prove fatal likewise by inducing Sleep. And hence it is that in Wounds accompanied with a profuse Hæmorrhage, a deficient Pulse and Sleepiness are very bad Signs. The like is also true when a great Portion of the Blood is in a manner intercepted from the Body by some internal Cause. In Animals killed by cutting the jugular Veins, a Snoring and Sleepiness follow, which is intercepted by Convulsions.

¹⁷ Such a phlegmatic Disposition of the Blood as accompanies a Leucophlegmatia, and which is succeeded by a Lethargy. I saw a Professor in this University whose Blood was so thick and sluggish that he was almost perpetually sleeping, and chose to be rather thus continually absent from Life, than to be truly dead.

¹⁸ The more corpulent or fat a Person is, the more the Arteries and Veins which lie under the Skin are compressed; and therefore in fat People the Arteries and Veins are much smaller than in those who are lean. But among all the Parts of the Body, the Brain only contains no Fat, and remains free from being compressed by that Substance. Therefore the carotid Arteries will remain free while the other Vessels are compressed; and thus the Blood will be derived with a greater Force to the Cortex of the Brain, and will by its Pressure produce continual Sleepiness. I have seen very fat People, for whom I have had a great Esteem, fall into a Paraplegia, when by walking in the Summer

Heats

Heats the Fat has been fused and forced into the Vessels of the first Order; from which Palsy they have been cured by bleeding and purging with Acids, as Chrystals and Cream of Tartar, &c. About two Years ago (*anno* 1724), I saw a Physician who was very fat, and who opposed or rather increased an imaginary Plethora by repeated bleeding, till at length he arrived at such a degree of Sleepiness, that he has ten times fallen asleep in the midst of his Discourse with me. I persuaded him to use Salt and the Essence of Wormwood, by which means I cured him. Such People as these are the better for Cares, Watchings, Labours, Exercises, spare Diet, acid Drinks, Vinegar, Spices, &c.

¹⁹ Such Wounds as extravasate the Blood, whence follows a Compressure of the Dura Mater and Brain.

²⁰ In the Sepulchretum Anatomicum of *Bonnetus*, we are furnished with Histories of People dissected after dying of most acute Diseases with Sleepiness. In these the small Vessels in the cortical Part of the Brain generally appeared stuffed full with red Blood, which in a healthy State they never admit.

²¹ In Infants the eight Bones of the Skull are so loosely joined together by Suture, that one may easily compress their Brain and render them apoplectic. Women sometimes secure the Heads of Children with such strait Caps, as throws them into Convulsions; and if the Force was a little more violent, they would be destroyed with an Apoplexy. But these Disorders are easily removed by removing the too great Stricture from their Head. I mentioned the Case of a Woman who had lost Part of her Skull before at §. 284.

²² *Drelincourt* has made the Experiment upon Dogs, who after their Brain had been cut out, lived without Sense and Motion like Vegetables.

²³ When the Cerebellum is affected in the same manner, as the Brain is affected to produce Sleep, inevitably Death is at hand. They who have suddenly a most severe Pain of the Head followed with a loss of Speech, perish of an Apoplexy within the space of three or seven Days, says *Hippocrates*. Upon opening the Bodies of such People, among other Causes Blood has been most often found extravasated from some ruptured Vessel into the Ventricles of the Brain, so as to compress its Medulla. But, as we observed before, the arched Part of the Ventricles is the common Sensory itself (§ 568.), that is to say, the Beginning of the whole Medulla of the Brain; no wonder therefore if Sleepiness follows from a Pressure upon this primary Origin of all the Nerves. But when the extravasated Blood penetrates to the fourth Ventricle where the Cerebellum lies upon the Medulla oblongata, and inserts its own Medulla in four Places into the Medulla of the Brain; in that case the Medulla of the Cerebellum is also compressed, the Extremity of which Medulla unites itself with the Medulla of the fourth Ventricle which is in form of a Pen, whence Death itself follows. In a word, a Compressure of the Brain excites Sleep, and even the most profound Sleep, an Apoplexy; which is not curable but by removing the Blood which compressed the Brain; but the Cerebellum being compressed occasions a perpetual Sleep, namely, Death itself.

§. 592. Sleep is impeded or hindered,

I. By a continual and flow Mixture of warm¹ watery Liquors with the Blood.

2. By

2. By every thing which is sharp or capable of *vellicating*² the Nerves of the Brain.

3. By strong *Passions*³ or Affections of the Mind.

4. From an Irritation of the Brain itself, whether from an external or an *internal*⁴ Cause.

¹ When we are concerned in urgent Business, which will not admit of being interrupted by our Sleep, nothing will more certainly keep off Sleep than Abstinence from solid Food, with the drinking of flesh Broths to the quantity of an ounce or two every half Hour; or instead of Broth, Tea, Whey, or any other thin Liquor often repeated. By this means Sleep may be drove off for a long time; and I remember that by these means Doctor *Sherrard* continued three Days and Nights without Sleep. I do not recommend this Secret to drive off the necessary Sleep but upon extraordinary Occasions, for I am too well acquainted that by this means the vital Powers are infringed, and Life itself shortned or rendered more calamitous; in a word, I have seen the fatal Effects of being destitute of the natural Sleep in many of my Friends.

² So long as the Spirits in the Brain are agitated, Sleep cannot take place. So long as any acrid Matter is applied to the Nerves, it continues to affect the Brain, and will induce Vigilance till either the Nerve is destroyed, or the irritating Matter removed. In *Denmark* there is a cruel kind of Torment, being a kind of military Punishment, in which the Offender is obliged to stand with his naked Feet upon an Iron Bar full of Spikes; so that when he falls asleep, he runs against
the

the Iron Spikes and is awaked, till a new Occasion of sleeping comes on, and he wounds himself again; and by this Punishment he is obliged to confess the Truth. The *Venetians* have a severe kind of Torture, in which the Offender is included in a Barrel beset with Spikes on the inside; so that on which ever side he lies he will be wounded.

3 For these Passions or Affections are intense Changes in the common Sensory, sometimes so lasting that the Person can never rest, new Motions continually arising in the Mind; and hence Watchings arise from Anger, Fear, Desire of Revenge, Grief, &c. Thus *Homer* polished his Bed by thinking upon *Ulysses*, as Women are used to polish Metals.

4 As, for Instance, from a slight Inflammation of the Brain. I have seen Men who in the Beginning of acute Fevers, have continued without Sleep for the space of seven Days and Nights, especially in the Beginning of a Phrenzy.

§. 593. Sleep therefore is that *State*¹ of the Medulla of the Brain, in which the Nerves do not receive so copious and strong an Influx of Spirits, as is required for the Organs of Sense and voluntary Motions, to exercise their Functions with Ease, and with Expedition.

¹ It is in short a Rest of the animal Faculties, by which I understand all the Senses and voluntary Motions. Watching is when all the animal Faculties, namely, the several Motions and Senses of the Body are capable of being readily performed; or it is that Disposition of the Spirits of the Nerves by which they are adapted to be received, transmitted, and to fill the System of the Nerves resulting

ulting from the Brain only, as we are assured by Experiment. For if but three Ounces of Blood are extravasated from a ruptured Artery of the Brain, so as to compress the Dura Mater, in that case the Action of the Heart will remain the same or become stronger, and the Respiration will be perfect; but neither will the Person see nor hear, perceive or imagine any thing, nor will he remember, judge or reason, nor yet move any of the voluntary Muscles, nor be affected with any Passion of the Mind. But in this case the Brain only is affected, and from its being affected in such a manner does Sleep arise. Natural Sleep therefore follows when there is such a physical Change or Condition in that part of the Brain, which is the Seat of the common Sensory, that the Spirits or Juices of the Nerves stagnate or become perfect at rest, whether that being from an impeded Secretion of them, or from some Change in the Circulation. In Sleep therefore all the Actions cease, which maintain the Commerce betwixt the Body and Mind; while those Actions only are continued which belong to the natural and vital Humours. Sleep is therefore an Affection of the Brain exclusive of the Cerebellum; and in the Brain Sleep may be termed that State in which the Motion of the Humours is impeded through the most subtle Vessels the Nerves, sent from the Brain to the Organs of Sense and voluntary Motion. Having proceeded thus far, it now remains for us to determine that State of the Brain from whence Sleep arises alternately during Life.

§. 594. The proximate Cause therefore of Sleep is perhaps a Paucity or *Deficiency*¹ in the most subtle Spirits, which being now spent or exhausted

exhausted require a long time and great Apparatus to prepare and recruit the same; hence therefore the finest Vessels being emptied, or not sufficiently replenished, will collapse for a time; or the Pressure of the *grosser*² Part of the Blood upon the Cortex of the Brain, which every way invests the Medulla, may be so great as likewise to compress the latter, and intercept the Course of the Spirits into the same Medulla.

¹ When the Spirits are consumed in a certain proportion, Sleep follows. This Juice which we sometimes call Spirits is deposited from the Cortex of the Brain into the Medulla, and employed as well in the Nerves of Sensation as in those which go to the Organs of voluntary Motion, in which this Juice seems to be exhausted or spent in a given time; but then there being no Fluid capable of entering these most minute Tubes to supply the place of that which hath been consumed, in consequence of that follows Sleepiness. For there is a certain time destined for every Humour in the Body to be separated, prepared, and perfected from the Chyle, Blood, Serum or Lymph; as there is also a certain time wherein those Juices are consumed, agreeable to the Laws of the animal Œconomy. From a certain quantity of Aliments in a given time is prepared a certain quantity of Urine, intestinal Fæces, perspirable Matter, &c. The Formation of the Chyle is limited to a certain time, as also is the Preparation of Milk from thence, with the Formation of Blood from the same. In oviparous animals, the Albumen of the Egg is so attenuated within the space of about twenty Days, not much sooner or later, by the Heat of the sitting

ting Hen, that from the Albumen are produced all the Members of the Chick, but that Liquor which seems to be contained in the smallest Vessels of the Brain must consequently be the most elaborated of all the Humours in the Body. For in the larger Vessels the grosser Humours only are contained, namely, in the sanguiferous Vessels which receive the Humours, which are as yet the most remote from an animal nature; namely, the Chyle is received into them. But the more any Vessels exceed the largest in Smallness, the more subtle are the Liquors which they convey; so that in the smallest Vessels of all, that Liquor is admitted, from whence results all the Actions of the human Body, and whose Particles are small enough not to exceed the Capacity of the least Vessels of the Nerves. From hence we infer, that to the Formation of animal Spirits, all the Actions of the human Body are required to concur, and that those Spirits are generated as they are consumed within a certain space of time; and from hence again it follows, that there must be a time in which few or no Spirits pass into the smallest Vessels from the Blood applied to the cortical Fabric of the Brain, and that therefore these smallest Vessels will collapse, in consequence of which follows a Propensity to sleep. Hence it follows, that the more violently the Body is exercised by the voluntary Motions, the sooner will there be a Necessity and Inclination to sleep; and from hence Sleep is said by a Proverb of *Solomon* to be the most pleasing to the Weary and Poor. Weariness and Sleep follow Exercises of the Body, because the most subtle Juices are dissipated by the Motions of the Muscles. Therefore a Person who in Health prepares only so much Spirits in the space of twenty-four Hours, as are sufficient to keep him waking sixteen
sixteen

sixteen Hours, he will require six or eight Hours for a Cessation of that Dispendium of Spirits, that the Body may prepare the Matter of the nervous Juice and form the same into Spirits; so that these six or eight Hours are required for Sleep. But the direct time necessary for Sleep cannot be absolutely determined, since more Sleep is naturally required in proportion to the loss of Spirits during the time of Vigilance.

² When the venal Blood is mixed with many crude, gross and cohesive Particles which have not yet been sufficiently attenuated; or when a great quantity of Chyle is sent into the Veins, Sleepiness follows from a Turgescence of the Vessels in the Brain, which Sleepiness may be continually removed by opening a Vein. *Sanctorius* has observed that from eight Pounds of Aliments taken into the Body within the space of twenty-four Hours, five Pounds of them exhale by insensible Perspiration. But the Particles which are thus exhaled must necessarily be supplied by others; and therefore when a Person sleeps but once in twenty-four Hours, he will become sleepy all that time during which the crude Chyle mixes with the Blood after Dinner. Hence it is natural for Animals to sleep when they are filled with Aliment. No Arteries in the Body are more dilatable from the Thinness of their Coats than those of the Brain, which yet are resisted and strengthened by their including Cranium (§. 234.). When therefore the Blood fills the Arteries of the the Pia Mater to a great degree, they will take up a larger space, and consequently compress the other Parts of the Encephalon into a less compass; and hence Sleepiness follows from the drinking of spirituous Liquors: for such Liquors act upon the small Vessels of the Brain, as Vapour ascending into the Head of a Still, namely,

X

ly,

ly, finding no Vent they cause a Rupture. Thus therefore spirituous Liquors rarify the Blood in the Brain and distend the small Arteries, which again compress the other small Vessels, whence Sleepiness follows, and continues until the Equilibrium is restored betwixt the sanguiferous Vessels of the Brain and those of the other Parts of the Body.—Hence then we infer, that the natural Causes of Sleep are, 1. A Consumption of the most subtle Humour of the Nerves, not sufficiently supplied during the time of Vigilance. 2. The Mixture of new and crude Chyle with the Blood, which renders the latter more thick and impervious through the small Vessels of the Encephalon. The *Romans* used neither Breakfast nor Dinner, but Suppers only, after which they used to compose themselves to sleep, which they extended generally to a long interval of time: and we observe, that Animals search out for a quiet resting Place as the Night approaches, having first supplied themselves with new Food.—Besides these Causes of Sleep there are innumerable other preternatural Causes, such as a Plethora, a Rarefaction of the Blood increasing the Pressure upon the Cortex of the Brain, a Leucophlegmatia, &c. which do not fall under our Consideration in this Place; since we here endeavour to explain only the Causes from whence the alternate Vicissitudes of Vigilance and Sleep follow. Add to this, that the Spirits generated in the Brain may be conceived to be more subtle than those of the Cerebellum; whence a greater Dispendium of the former may be required to maintain these physical Actions, and for the same Reason too the former may be sooner exhausted.

§. 595. The Cause therefore of natural Sleep, may be every thing that can produce these two Particulars, (§. 594.) §. 596.

§. 596. From hence we may be able to understand the Effects of Sleep, during the time of which several *Actions*¹ of the Body cease; (§. 593. N^o. 1, 2, 3, 4.) which Organs together with the *Muscles*² (§. 590. N^o. 3.) are in a State of Rest; the Spirits difficultly *flow*³ through them (§. 593.), and are therefore less *consumed*⁴, while at the same time the solid Fibres both in the Nerves and Muscles receive little *Alteration*⁵ and are not wore away, but an *Equilibrium*⁶ is procured in all the Vessels throughout the Body; the Humours being sent through the Vessels with an equable Pressure and with an equable *Velocity*⁷.

¹ That is to say, all the animal Actions, the five external and internal Senses, with the Motion of the Muscles subject to the Influence of the Will; which Actions perfectly cease in Sleep, though if we compare them, we shall find that they require much greater Supplies than all the vital Actions taken together. No one will deny, that a Horse which has stood twenty-four Hours at Rest in a Stable must suffer a less Motion and Consumption of his Organs, than if he had been running all that time with somebody upon his Back. The Actions therefore of People who are awake, are much more weighty and numerous than the vital Actions of those who are sleeping; and therefore most of the Actions of the human Body cease during the time of Sleep. Even a Person cannot so much as speak but the Blood will be agitated more swiftly, and therefore they who pronounce aloud with a quick and clear Voice, are by that means

as much fatigued as if they had been running. We may even become too hot by too intense and profound Meditation. But all these Actions which make up the greater Part of those which employ human Life, cease during the time of Sleep.

² All the Muscles which are tense and in Action while we are awake, are flaccid and at Rest during the time of Sleep. Even the most common Observations teach us, although they are neglected from their Familiarity and Easiness, that the Muscles of the human Body are always in Action when we are not asleep. You would perhaps believe that a Man does not labour when he stands erect, because the Action is so familiar that it communicates no Idea of Force to the Mind; but at the same time if a Person stands with his Arms extended, the Action will be found very violent and painful: for then the Muscles of the Toes, Meta-tarsus, Tarsus, Legs and Thighs, with those of the Pelvis and Vertebrae of the Spine, from the Os sacrum even to the Atlas, with those of the Head and Thorax, all operate as it were in a determinate manner (§ 639.). That they do thus act while we are awake, notwithstanding our Insensibility thereof, is evident from observing the Posture of the Body when it is inclined to sleep; for the Muscles then ceasing to act, the Body inclines one way or the other, and the Parts collapse usually into the most loose and easy Posture. The Organs of the Body therefore which acted while we were awake, cease from their Operation during the time of Sleep. But these Organs are the voluntary Muscles which become flaccid in Sleep, and do not transmit their Humours as is usual in the time of Vigilance.

³ For in the time of Sleep the animal Spirits flowed through the optic Nerve to the Retina, or through

through the auditory Nerve to the Vestibulum, there could not be the least Rest either in the common Sensory or in the voluntary Muscles; but in Sleep we affirmed that the Organs of Sense and voluntary Motion are at Rest, and therefore the Cause which used to move those Muscles does not move through them while we are asleep. In a Person who is awake the Arm may be easily extended; but so soon as that Man is in a soft Sleep, the Arm will be continually pulled down by its Weight; and therefore at that time that Cause ceases to enter the Muscles which rendered them tense and ready for Contraction; but that Cause is the Will or Mover of the Spirits through these Organs of Motion, and therefore the Spirits themselves are at Rest.

4 Nothing will exhale nor any Part be pressed to Action, since there is no new Supply of Spirits received.

5 It is an universal Law, prescribed to all Bodies, that the several continuous Particles or Elements of the same Body attract each other; and therefore the Cause which distends the same Body must distract the elementary Particles from their Connection. But when the Cause of Attraction only remains while the distracting Cause is removed, then the Power of the former is continually increased, so as to bring those adjacent Particles as near as possible to each other in the same Body. Therefore the Fibre of a Muscle which is free from all Distension, will restore itself to its former Shortness; and hence a Muscle which has not been moved for a long time becomes at last immoveable. Surgeons observe in a Fracture of the Ulna, that if the Part affected is secured with Dressings and Splints, and not moved for the space of six Weeks successively,

after removing all the Bandages, the Flexion of the Cubitus or Elbow will be then found impracticable; and therefore the Muscles concrete together, merely by long continued Rest. But the smallest Vessels not being distended, have their Sides grow together in the same manner, so as almost to form solid Threads. The same Accident may also arise from the Nerve being compressed by the Artery.

² While we are sleeping there is an Equilibrium produced betwixt the Heart and Blood-vessels; for when the animal Spirits are wanting in the cortical Substance of the Brain, the sanguiferous Vessels being then less pressed will be more distended; and on the other hand the medullary or nervous Tubuli will be then more compressed. Therefore the Influence of the Mind upon the Heart ceases, while all the Vessels are in Equilibrium with respect to the Heart, which is almost placed in the Center of Gravity; and therefore as the Circulation of the Blood depends entirely upon the Heart, it consequently follows, that the Motion thereof must be extremely equable during Sleep. But in the mean time in what Office is the Mind employed? Whether or no is it idle? No one will pretend to say, since the Memory does not act during perfect Sleep. When we are inclining to sleep there remains as yet some Consciousness and Memory; but in a profound Sleep, there does not seem to be the least remains either of Memory or Consciousness.

⁷ For at that time the Blood is equally distributed to all Parts of the Body, and every Part takes its due quantity, agreeable to its Magnitude and Distance from the Heart.

§ 597. But in Sleep the Motion of the *Heart*¹ and Lungs, with the Actions of the *Arteries*² and *Viscera*³ are increased (§. 590. N^o. 5, 6, 7.); nor is there any Change or Destruction at that time made in them from the Action of the Senses and *voluntary Motion*⁴ then ceasing (§. 590. N^o. 1, 2, 3, 4.); and therefore these Effects follow from those Actions which immediately depend thereon, and may be reckoned, 1. A stronger and more equable Circulation of the *vital*⁵ Humours through the Vessels, which are then more free, lax and open, without being impeded by the various Contractions of the Muscles; hence therefore the Impulse of the Humours into the *lateral Vessels*⁶ is indeed less but more equable, and the Impulse of them through the larger Vessels is likewise stronger and more equable; thus therefore the small lateral Vessels will be gradually filled, will transmit less of their Humours, and at length in a manner quite *rest*⁷ or stand still with their contained Fluids; the lateral *Follicles*⁸ or Cells of the adipose Membrane will be filled and distended with the more slowly moving Oil or *Fat* *⁸, as will be also the Follicles of the several Glands with their respective Juices; so that at length the Circulation continues almost only through the sanguiferous Vessels, becoming gradually slower and at last scarce perceptible, if Sleep is too long continued; and in the mean time the accumulated Fat defends the internal Parts like

a Balsam spread round them, and affords slowly some small *Nourishment* ⁹ when there is urgent Necessity. 2. In moderate Sleep then the Matter of the *Chyle* ¹⁰ is very commodiously changed into Serum, the Serum into still thinner Humours, and those thinner Humours into the Matter of Nutrition. 3. The Attrition of the solid Parts which slightly cohere together, becomes gradually more gentle. 4. The Secretion of the *Skin* ¹¹ is increased, while the other Secretions are diminished. 5. The *lost Substance* ¹² is at this time best repaired, since the Humours are renewed by a continual just and *equable* ¹³ Repletion, and the *solid Parts* ¹⁴ at the same time are best repaired, since the Causes which impede, disturb, or destroy Nutrition then cease; and in the mean time that the nutritious Matter is most happily prepared, there is an Aptitude in the Vessels to receive the same, and a Disposition of the Humours to enter into them, while the Causes which apply and consolidate the nutritious Matter at the same time freely act. 6. Hence therefore there is a new Production and Accumulation of animal *Spirits* ¹⁵ or at least the Matter of them throughout all the Humours, and an Accumulation of them in the smallest Vessels which are thus filled.

¹ That the Motion of the Heart is increased appears from the Pulse (§. 590.) and increased Heat; but the Heat of the Body is not increased, but by a swifter Contraction of the Heart discharging more Blood in a given time; but more
Blood

Blood cannot be expelled from the Heart, without more being received and conveyed from the right Ventricle to the left; nor can this last be performed without a swifter Protrusion of the Blood through the Lungs, which must be necessarily accompanied with a more quick Respiration.

² The Force of the Arteries is that Resistance by which they oppose Dilation from the Heart, (§. 213.) and the Measure of their Force is the same with that of the Impulse of the Blood received from the Heart (§. 215.) Since therefore the Contraction of the Arteries is equal to the Contraction of the Heart, it follows, that increasing the Force of the Heart will increase the Action of the Arteries. But if this Argument is denied, and you suppose the Force of the Heart to be increased while that of the Arteries remains the same, those Vessels will then be continually more and more distended with Blood beyond what their Force is capable of propelling; whence after a few Pulsations Death itself must follow. If then the Force of the Heart is increased in the time of Sleep, that of the Arteries must be likewise increased proportionably; whence it follows, that the Action of all the Viscera upon the Blood and their several Humours will be increased, for all the Viscera are composed of mere Arteries. All the Causes therefore which result from the Action of the Heart and Arteries, will be stronger in Sleep than during the time of Vigilance.

³ That is to say, so far as the Viscera are moved by the vital Powers; for they are subject to a very inconsiderable Motion, from the Influence of the Mind by the Nerves. The animal Motion indeed exceeds the Motion of the Humours in Sleep; namely, when *Farenheit's* Thermometer descends to the thirty-second Degree, Water freezes; but
if

if it falls to the tenth Degree, all Animals then expire if they sleep (without any Covering) exposed to the external Cold. For the vital Motion only cannot then prevent the freezing of the Humours. But such a Degree of Cold fatal to those who sleep may be overcome by running in the open Air, or by other violent Exercises and voluntary Motions of the Body; whence it follows, that the animal or voluntary Motion of the Body generates a greater Heat than the vital Motion only.

4 Which Motions in a Person who is waking, produce a great Variety of Alteration in the Action of the Arteries and Veins; but which have now no Influence when the Action of the Heart only continues. In Sleep the Action of the Heart continues equally the same, to which the Action of the Arteries correspond, together with the Action of the Viscera, which are all composed of Arteries. The Application therefore of the Powers of the human Body to assimilate the crude Juices is on all Sides increased, and at the same time rendered equable. The assimilating Powers therefore act most when the other Powers are at Rest.

5 Namely, those Humours which pass through the Heart to the Lungs, from thence to the Arteries and Veins, and then again to the Heart in a continual round; but not those Humours which flow into the lateral Vessels, for the Motion of these is almost suppressed while their Impetus is increased.

6 By the lateral Vessels we intend the serous Arteries, with the lymphatic, perspiring and nervous Vessels, &c. In a Person who is sleeping the Pulse and Heat increase; but Heat results from the Action of the Vessels of the first Order, that is to say, of the Blood-vessels both Arteries and Veins, from whence all the other Vessels derive their

their Heat ; and therefore since Heat is increased in Sleep, it is evident that there is a greater Action of the sanguiferous Vessels at that time. But then the Juices which are conveyed through the smaller Vessels must necessarily stagnate in the time of Sleep. For these smaller Vessels are filled by the Action of the sanguiferous Arteries and their Contents, and are not so much moved forward by the Action of the Vessels themselves, as by the various Motions of the adjacent Muscles protruding them towards the Heart : For while we are sleeping the thinner Humours continue to pass off from the sanguiferous into the ferous Arteries ; so that the sanguiferous Arteries being gradually exhausted in Animals that sleep whole Months together, towards the End of their Sleep the Pulse is scarce perceptible. Thus the Serum is derived from the sanguiferous Vessels into the smaller ferous Vessels, where it stagnates without circulating. There are some who believe that the Serum cannot thus stagnate because it is propelled forward by the succeeding arterial Blood, in the same manner as the liquor contained in one Leg of a Siphon, does by its descending Weight raise that which is contained in the other Leg. For all the vessels of the Body, say they, may be compared to an inflected Tube or Siphon, so that the Humours contained in one Leg cannot descend without raising the other ; and the Liquor contained in one Leg may cause that in the other to descend. But it may be easily proved by Experiment that this is without Foundation. Let a Person sit still a whole Day, and he cannot be said to be truly at Rest, for he will move sometimes one Muscle and sometimes another ; so that in that State of supposed Rest the Humours will continue to be propelled through the lateral Vessels. But let the Person
sleep

sleep in the same Chair but a whole Night, he will be surpris'd in the Morning to find his Legs swelled as in a Dropsy, even though he was before in Health; but by walking this Tumor of the Legs is suddenly dispersed. Our Humours therefore stagnate in the smaller Vessels, not so much from their Weight, as from the Deficiency in the Action of the Muscles; for want of which the Humours propelled into the lateral Vessels remain there stagnant without being propelled farther, since they are placed farther from the Power of the Heart.

⁷ The Distribution continues equable, but the gross red Blood cannot pass into the serous Vessels, and all the other Juices stagnate in their respective Vessels. Hence when Sleep has been continued a long time, the Circulation is little or nothing, except through the sanguiferous and serous Arteries, and such as cannot be compressed as having no adjacent Muscles, namely, the Medulla of the Brain and Spina dorsi. Hence animals which I have kept in large Vessels for several Months, I have found living and not at all consumed.

⁸ No Animal can be fat so long as the animal Motions are stronger than the vital; but Sleep renders People fat, since none of the Humours are more viscid than the Oil or Fat. In sleeping Animals therefore this tenacious Fat will be deposited into the adjacent Cells of the adipose Membrane, till at length the Animal is buried in his own Fat.

* ⁸ It is well observed of the Poet *Martial*, (*lib. 13. epig. 59.*) that the wild Mouse commonly called a Dormouse sleeps all the Winter, and is even fatter at the time when it receives no other Sustenance but from Sleep. These kinds of Animals towards the latter End of the Winter have scarce any Motion. I observed something wonderful in the Tortoise, which Animal has in a manner

manner four Hearts and Lungs, and is able according to different Circumstances to propel the Blood either through the Heart only without pervading the Lungs, or through the Heart and Lungs together, breathing at the same time according either as it uses or abstains from muscular Motion. This has been well considered by the excellent Anatomist *Du Verney*, in the *Memoirs of the Royal Academy*, ann. 1693. p. 310. Towards the Beginning of Winter the Tortoise buries itself in the Sand, so that it is hard to discover where it lies hid, and thus it lives without Respiration, creeping farther under the Earth in proportion as the Cold is more severe. But at the Return of Spring it by degrees creeps nearer the Surface, and at length comes out of the Sand, leaving no Marks by which one can trace out the Place where it lay; and being thus exposed to the Air, it is both vigilant and breathes. But even the more active Animal the Swallow lies dormant without Motion five Months in the Year; and the same is also true of Frogs. Likewise the Bear, the Badger and Dormouse pass the whole Winter in Sleep without Food. But since in these Animals the adipose and glandular Cells are not emptied of their Contents, by the Motion of the Muscles ceasing for so long a time; therefore Fat is accumulated in them, and those Disorders frequently produced which arise from a Distension of the Glands.

9 Animals which sleep a long time do at last prey upon their own Fat, which returns into the Blood (§. 333.). The Bear passes the most severe Winter by sleeping in his Den, where he at first sleeps and snores very soundly, and then growing by degrees hotter, he sweats out a kind of Oil, with which the whole Animal is bedewed as with Lard; but at last the Blood becoming more acrid
consumes

consumes this Lard, till at length the warm Season returning awakes the Animal. If you kill this Beast in the midst of the Winter in his Den, he is found very fat, but in the Spring he comes forth from his Den extremely lean and almost like a Skeleton. Hence therefore it is evident that during the first Part of this Animal's long Sleep an Oil or Fat is separated from the Blood, with which the Body is preserved and supported; but at length this Oil being dissolved and returned into the Veins, supplies the Blood instead of Chyle.

¹⁰ In Sleep the Motion of the Blood is increased through the Arteries and Veins of the first Order; by which means especially the crude Chyle is attenuated. Hence therefore during Sleep the Chyle is converted into Milk, Milk into Serum, and Serum into Blood; but the Blood itself is at the same time attenuated again into a second Serum, and that into a more thin Lymph in several degrees of Tenuity, being at last elaborated into the animal Spirits themselves. This Elaboration is also promoted by the Atmosphere of warm Vapours proper to every Person, which is retained by the Bed-cloaths, and being returned upon the whole Body, warms and relaxes like a vaporous Bath.

¹¹ A healthy Person sleeping eight or at most ten Hours, becomes considerably lighter than if he slept not so long (§. 430.). When a healthy Person sleeps eight Hours he will not perspire much during the first five Hours, but the three last Hours he will perspire copiously, and will become much lighter, as is evident to the Sense and by the Steelyard, as *Sanctorius* has observed. For the crude Humours are during the first five Hours attenuated and digested by the repeated Action of the vital Powers, so as to be afterwards easily exhaled during the last three hours,

During

¹² During Sleep the nutritious Elements or Particles are equably distributed to the several Parts required to be nourished.

¹³ Men and other Animals sleep with their Limbs inflected or drawn up, by which means the Vessels are compressed and a greater Resistance is made to the Circulation by increasing the Number of Inflexions and Angles; whence the Attrition and Heat of the Blood is increased. — But when Animals are hot they stretch themselves out.

¹⁴ During the time of Vigilance the Action of the Muscles extend the Nerves and Fibres of the Body, compress the Blood-vessels, &c. (§. 402.); whence Attrition and Lassitude follow: but during Sleep the Vacuities which were formed in the time of Vigilance by an Abrasion or Dislocation of the nutritious Particles, are again filled up with Particles like the former (§. 445.). The time of vigilance therefore destroys the Body, but during Sleep it is repaired. After the Body has been exercised to great Weariness, a Pain is felt throughout the whole; but if then laudable Sleep follows, the Person soon after perceives himself in a manner renewed; namely, in the Day-time the muscular Fibres labour till they are almost broke asunder, from whence follows that Pain and Weariness; but in the Night-time by Sleep, the Parts are equably replenished and repaired, so that the former Strength is in a manner recovered.

¹⁵ A Person by long watching consumes a great Part of the most subtle Humours, such as are adapted to distend the most minute Tubuli of the Nerves; but then during the space of eight Hours Sleep, there is little or no Dispendium or Loss of these Particles; but in the mean time a Heat diffused through the Body, like that of a sitting Hen; restores the same quantity of the like subtle Humours;

mours ; and therefore Sleep is necessary in proportion to Exercise (§. 594.). But when Sleep is over long continued, the Muscles by too much Rest become unfit for future Action, and the whole Body becomes dull.

§. 598. Every Part being thus recruited by Sleep, there will be again an *Aptitude*¹ in the Body to Vigilance, and an Indisposition to sleep ; so that an exciting Cause approaching the Person will wake again.

¹ Vigilance therefore does not always follow Sleep as a necessary Consequence (§. 590.) ; only the Stock of Spirits is recruited, and if any stimulating or exciting Cause approaches, the Person will continually awake. A Comic Author in a particular Scene introduces with *Aurora* the returning Labour and Cares of the Day, which are abhorred by the Sun, whose powerful Rays excite those who are half diseased and in Pain and calls them to the Plough, when they would have found a Cure for all their Difficulties if they were but permitted to sleep a little longer. Sleep itself therefore does not awake the Patient, but it supplies or provides proper Matter in due quantity and quality sufficient to render the Person vigilant when he is awaked by some exciting Cause. When a Child awakes it is usually convulsed, stretches all its Limbs, and in a little time after rubs and opens its Eye-lids, gapes or yawns to accelerate the Blood through the Lungs into the left Ventricle of the Heart ; and then all the Muscles are relaxed and in a manner opened, by which they are fitted to be supplied with Spirits sent from the Brain, which compleats the Vigilance or Awakening.

§. 599. From

§. 599. From hence we may be able to give a Reason, why a Person cannot Sleep with his Head hot and his Feet *cold* ¹ ?

Why *Drunkenness* ² follows from spirituous Liquors, and afterwards Sleep ?

From whence proceed *Dreams* ³, and from whence walking in the Sleep ?

Why after a laudable Sleep confined within the space of eight Hours, the *Perspiration* ⁴ is twice as large as it would have been if the same time had been spent in Vigilance ?

Whence it is that by sleeping *too long* ⁵ the Head becomes heavy, the Senses dull, the Memory weak, the Body cold, phlegmatic, fat, heavy, or unactive and weak, with an Inaptitude in the Muscles to Motion, and an *imperfect* ⁶ Perspiration ?

From whence Sleep *long continued* ⁷ may support Life for a considerable time, without *Food* ⁸ or Drink ?

Whence it is that after a laudable Sleep all the Muscles are usually *expanded* ⁹, *yawning* ¹⁰ is repeated, and the Sharpness of the Judgment, Activity of the Muscles and Strength of the Nerves return ?

Whence it is that a *Fætus* ¹¹ sleeps always, that *Children* ¹² sleep often, and growing or young People more than adult or old People ?

Lastly, for what end those who are *recovering* ¹³ from violent Diseases sleep much longer than when they are perfectly well ? Why we are sleepy after *Meals* ¹⁴, and active *before* ¹⁵, and why we have so large a *Brain* ¹⁶ ?

They who go to bed with their Feet cold and their Head hot in Winter, never fall into a Sleep until their Feet begin to be warm. There is a History relating to this Subject given us by *Carolus Piso*, who had a Lad studying with his Companions in a cold Place several Days, himself and all of them fell into violent Catarrhs and Disorders of the Head; namely, because the Circulation of the Blood in the Head was increased too much by Vigilance and Meditation, while its Motion thro' the Feet was impeded by the external Cold, so that the Blood was derived from the contracted Vessels of the Feet towards the relaxed Vessel of the Head; and therefore Sleep could not follow, which supposes an Equability in the Circulation of the Blood.

Of Drunkenness there are three Degrees, in the first of which there is a great Readiness to all the Functions of human Life, even greater than in a healthy Person, and accompanied with extreme Gladness. Thus *Horace*:

*Tu spem reducis mentibus anxiiis
Viresque, & addis cornua pauperi,
Post te neque iratos trementi
Regum apices, neque militum arma.*

Lib. III. cap. 22.

The second Degree is a kind of Delirium which increases imperceptibly, till at length the Will loses its Influence upon the Limbs, Tongue, and all the other Actions proper to human Life. The last is a dead Sleep next to an Apoplexy, in which the whole Body continues immoveable, and does not perceive even the greatest Injuries. This follows from the Spirit of Wine mixing with the Blood, and as a Body extremely volatile soon flying to the Head more than any other Part, where
it

it expands the cortical Substance more than the Resistance of the Medulla is capable of supporting. For such is the Nature of inflammable Spirits that they neither coagulate the Blood in the Vessels, nor do they arrive into the Vessels with their full Power, but insinuating into the smallest Vessels, they disturb the Motion of the Humours, which causes a Delirium. Hence also Sleep follows from the Use of the most volatile Medicines. From plentifully drinking of inflammable Spirits, a continual Sleep follows, which hardly continues longer than an Hour; for Alcohol powerfully inebriates, because it is so volatile as to fly into the Air with the least degree of Heat; and it appears by surgical Experiments, that by touching the naked Nerves they become insensible therewith; and why may it not produce the same Effect when taken by the Mouth internally? On the contrary, the drinking of the strongest Ale, such as Mum in a large quantity, occasions a Sleep of long standing, perhaps of two or three Days; namely, because the spirituous Particles inviscated in the Ale expand themselves more slowly. But Liquors which have not been fermented do not inebriate, because their Particles are too gross to ascend or fly up to the Head.

3 When any Part of the Medulla of the Brain is empty and collapsed, while another Part remains free and distended with Spirits, the Person dreams; and therefore dreaming is a kind of half Vigilance or imperfect Sleep. Hence we need not so much wonder at those who walk in their Sleep, for when that Part of the Brain remains free which appertains to muscular Motion, the Spirits will then be as necessarily detached to the Muscles by an internal Cause without a Consciousness of the Mind, as in a State of Vigilance; much in the same manner as

we walk in deep Meditation, without being at all conscious that we do walk. Those who walk in their Sleep therefore are but half asleep. From hence we may understand why a Person will sleep sound who has been much tired, unless the Fatigue has been such as to produce Pain in the Nerves, which impedes Sleep and intermixes the State of Vigilance with that of sleeping; and why those are inclined to sleep who do not sufficiently exercise the Body in proportion as they meditate, as also when they have lain too long a-bed in a Morning. But concerning Sleep from other less frequent Causes, as from the Atrabilis, it is not the proper Business of this Place.

4 The concoctive Powers of the human Body by which our humours are attenuated, are equally applied to all the crude humours in the Body. Nor ought the Body to be exercised after Meals, in order to preserve Health, as I was formerly persuaded with the common Opinion; for this is repugnant to Nature, who inclines all Animals to sleep after Meals, at which time the Body cannot well be exercised without some Uneasiness. But Exercise of Body is the best before Meals, upon an empty Stomach, according to the ancient Advice of *Leonidas*, who had the Care of *Alexander* in his Youth. But even that Perspiration is greater in Sleep, is demonstrated from the Observations of *Sanctorius*. If of two healthy People one sits still at the Table or walks about the whole time, while the other sleeps three Hours in a Bed, by weighing both of them afterwards, the Person who has been sleeping will be found much lighter than the other; because the Skin of the latter has been kept continually warm and lax while the other has been cold; even though one cannot be able to sit still without using animal Motion.

Since

5 Since we demonstrated that Sleep arose from a Rest or Deficiency in the Spirits, which are to be applied to the Origin of the Nerves, we thence understand that the muscular Fibres during Sleep are scarcely distended; they will therefore be contracted very strongly from their own inactive Power, so that they cannot be easily on a sudden distended and moved by the nervous Juice. So long therefore the Fibres rest and become very unfit for Motion, whence the rest of the Symptoms follow as before-mentioned. The Husbandman cannot pass one idle Hour without sleeping; and therefore if he was to spend all the Holidays in sleeping, he would become weak and incapable of his Business, unless he exercised himself with some rough Play, as that of the Ball or the like. One who has been sleeping ten Hours will be quite dull all the rest of the Day, unless the Body is exercised after Noon; for by that means Alacrity and Activity may be recovered.

6 Because the smaller Vessels are indeed filled, but they want Motion to propel the Humours through the Extremities of those Vessels by the Pressure of the Muscles. But if Sleep is continued longer than usual, then the fat being accumulated buries and compresses the smaller Vessels, so as to prove another Cause retarding the Motion of the Humours, and suppressing the Perspiration.

7 I cannot give credit to those over ridiculous Christians, who relate the Story of the seven Sleepers for true. Yet I believe it possible for a Person to live a long time without Food or Drink, provided only the Circulation is continued through the larger sanguiferous and serous Vessels. After five Hours Sleep the Humours are derived into the cutaneous Vessels, and a plentiful Perspiration is begun; but when the Perspiration is over, the cuta-

neous Vessels contract and shut up their Pores; whence a Person may survive a long time in that manner, till he is at length awakened by a slow and pleasing Consumption (§. 597.)

⁸ Thus in the Species of *Erucæ* or Caterpillars among Insects, as well as in other Animals which pass the Winter in Sleep, they are supported without Food. The Cause of so long a Sleep in these Animals may be from the great Viscidity of their Humours, which are not propelled and exhaled from the Surface of the Body, but are only drove by a little weak Heart to the small Brain, while a small Portion circulates through the Lungs. Hence there is but little waste of the Humours, and the Animal continues a long time in the same State; but at the Approach of any Heat whether artificial, (in the midst of Winter) or natural in the Spring, the Humours will be expanded and the Lungs filled; so that the Animal becoming more active will now require Food. But the Humours are prevented from Putrifaction during their Rest, by the Cold, as also by the Exclusion of the Air. Even by excluding the Air a human Fœtus may be preserved for many Years uncorrupted. In other Animals that sleep in the cold of the Winter, which are very numerous, the Reason is different. In those who are asleep the Spirits are not consumed as in Vigilance, and the Humours are derived into smaller Vessels, through which they are very hardly moved forward; but then all the Oil or Fat is poured out round the Sides of the Vessels, so that the Animal is as it were covered over with an oily Crust, by which it is preserved from corrupting during the first Stage of Sleep. But when the first Stage of Sleep is over, as, for Example, when the Animal sleeps twenty-four Hours when it is used to sleep but ten; from that time the Motion of the
Blood

Blood continually grows less and less, so that at last one may doubt whether it has any Motion at all. *Lewenhoec* received some Bats in the Winter which were found concealed behind some Hangings, but could not perceive any Motion in their Blood; but by bringing them to the Fire, their Blood began to move very swiftly. This is still more evident in Frogs, which I have found lying still in the Winter-time as if dead, insomuch that the Body would not move even by cutting off a Leg; but by exposing them to the Sun they soon recovered their former Vivacity, so that I could hear them croaking in the Glass. Hence it is that these kinds of Animals always covet to be in the Sun which gives them new Life. But if such an Animal is not revived by any Heat, either of the Sun or of some other Body, the Blood at length moves so slowly as to become acrid even by Rest; and dissolving the adjacent Drops of Oil after Dissolution, they return with the Blood of the next adjacent Veins.

⁹ In profound Sleep the Spirits, which are the Authors of all the voluntary Motions, are at rest, as well in their Origin the Brain and Nerves, as in the Muscles. But when an Animal awakes the Spirits begin to move, and the Mind bends its Force towards the Parts to be moved, whence generally follows an equable Inflection of the Muscles.

¹⁰ Yawning is a deep Inspiration, by which the Course of the Blood is accelerated through the Lungs, whence it passes most swiftly into the left Ventricle of the Heart, and from thence it returns with a greater Pressure to the Brain and Cerebellum by the Arteries.

¹¹ The most healthy Foetus sometimes startles or stretches itself at small Intervals in the Womb of its Mother, but all the rest of the time of its

inhabiting in that Part, it continues at rest as if it were dead; and therefore it is very probable that it is then sleeping. But it is credible, that when the prepared Chyle is poured into the Mother's Blood in large quantities, as must happen towards the Morning or any other long Interval after a Meal, then the Foetus usually bestirs itself. But in Sleep Nutrition is the greatest, and the Attrition or Destruction of the Parts little or nothing; and therefore the Foetus grows more in the nine Months of its Gestation, than it ever does afterwards within the same space of time, till it becomes an Adult; for in this short time it grows up from an invisible Point, supplied from the Semen masculinum, even to the Weight of eight, nine or thirteen Pounds (§. 675.); but such an Increase is never afterwards performed from the Birth, because the Sleep and Nutrition are both less. But the Cause of so long Sleep in the Foetus, is the prevailing Force of the Heart over the Resistance of the Humours and Vessels; but the Action of the Heart is vital; and therefore it overpowers the animal Actions; and so long does Sleep prevail over Vigilance. The Foetus, as far as we can tell, has no Ideas, nor has the new-born Infant any other than that of Pleasure and Pain; but in this early Stage of Life the Body receives its greatest Increase and Growth, which lessens as the Brain is more exercised.

¹² Children who only awake when they want to be suckled, sleep almost all the rest of the time. But in adult People the Body is only maintained as it were in the same State for the same Reason.

¹³ In all acute Diseases there are always tedious Watchings, unless the Brain itself is affected. I have seen thousands of young People in the Small-Pox, Phrenzy, ardent Fevers, Pleurisies, &c. who have not slept Night nor Day for a whole Week
toget-

together, but when they have been recovered, their Body has been lighter by one third Part of its Weight, so that those who have been very fat have been reduced almost like Skeletons. And therefore these Watchings with Sweats or other Evacuations have in this manner wasted the Body. So long as the Disorder rages the Patient can rise up and move his Body, but when the Disorder is off he cannot support himself, but sleeps Night and Day; and in this Case the Patient's Friends, very often without Reason, are afraid of an Apoplexy; for nothing more powerfully recruits those who are recovering than Sleep, if at the same time they are supplied frequently with small quantities of laudable Nourishment.

¹⁴ The Drowsiness which follows after a Meal is usually ascribed to the crude Chyle, which being conveyed to the Brain with the Blood, impedes the Motion both of that Fluid and the Spirits thence separated. But this Dulness does not follow when we use Food of easy Digestion, from whence much Chyle is prepared; but it follows chiefly from great quantities of hard Aliments distending the Stomach, and increasing the Circulation upward, by compressing the Aorta; and retarding the Course of the Blood downward. When we have eat too large a Supper we frequently pass the whole Night restless or with a half kind of Sleep, which renders us dull the next Day. If now we evacuate from the Stomach the offending Matter, we soon become chearful and easy. Nor ought it to be objected that from this greater Derivation of Blood to the Brain, more Spirits ought to be separated, and that therefore a Chearfulness ought to follow instead of Dulness; for the sanguiferous Arteries being too much distended compress and obstruct the other smaller Arteries.

¹⁵ We are the most active a considerable time after a Meal, as the Spirits then abound most ; but this Abundance of the Spirits does not follow from the last Meal, but from a long and successive Series of Changes, by which the Serum of the Blood is attenuated into more subtle Juices.

¹⁶ We are furnished with so large a Brain, because that Part in Animals is proportioned to their Ingenuity ; and therefore the Brain is largest in Man, and next after him it is largest in Apes, Dogs, &c. in proportion to the rest of the Body. It is not easy to meet with a Person foolish from his Birth, whose Brain has not been altered from its natural or spheroidical Figure. In general, the larger the Brain the more ingenious is the Animal, and the larger the Cerebellum the stronger the Animal ; and therefore the strongest Animals have but a small Brain.

§. 600. But the Reason why the Heart is not relaxed and *inactive*¹ during Sleep like the other Muscles (§. 590. N^o. 3.) but on the contrary acts more strongly, contracting and dilating alternately, will appear evident if we attend to the following Particulars: 1. The Difference betwixt the *Brain*² and Cerebellum, the former being *soft*³, furnished with *Cavities*⁴, and encompassed with venous *Sinus's*⁵ of different Courses, being capable of Expansion and Compression, and being likewise spread externally with Circles of the larger Arteres ; but the Cerebellum is more solid and *compact*⁶, has no Cavities, nor is it pressed or encompassed by any venous Sinus's, being incapable either of *Expansion*⁷ or Compression, only furnished with small Arteries and Veins like

like the *rest* ⁸ of the Brain. 2. That the *cardiac* ⁹ Nerves derive their Origin from the Cerebellum only. 3. That the *coronary Arteries* ¹⁰ of the Heart are filled and emptied at opposite times with those of all the other Arteries in the Body; and that the like is also true of the coronary Veins. 4. That the Ventricles of the Heart are filled at the same time with the coronary Vessels. 5. That the Auricles and Ventricles of the Heart are filled and emptied, contracted and relaxed alternately. From all these Considerations it will appear, that the Causes of the Heart's Contraction are continually renewed and destroyed, acting, and ceasing from Action. But whether or no the vital Spirits of the Cerebellum are more *tenacious* ¹¹ and durable than the animal Spirits of the Brain, must still remain a Question? But why does the *peristaltic* Motion also never cease?

¹ We come now to a very difficult Question, namely, why the Muscles of the Heart and its Auricles, the venous Sinus's, with the Arteries, Diaphragm, those of the Abdomen with the intercostal Muscles; and lastly, the Muscles for the peristaltic Motion of the Intestines never cease to act in Sleep, at which time all the other Muscles in the Body are relaxed; but on the contrary, they are observed to act more powerfully than during the time of Vigilance (§. 590. N^o. 5, 6, 7.). This Question has been aimed at in all Ages, nor yet has it been resolved since the time of *Harvey*, for want of sufficient Attention and regard to the *Harvean* Demonstrations.

² The wise Creator has made the Cerebellum different from the Brain. We said before that the Brain in Man is much larger in proportion than in other Animals, who have this Part less in proportion as they are less human in their Faculties, as they perform fewer of the animal Functions, as they are furnished with Senses less acute, and are less ready for the Performance of voluntary Motions; in a word, as they approach nearer to a vegetable Nature. In the Skull of a Whale, preserved here at *Leyden*, the Cavity for holding the Brain will hardly receive one's Fist. But in proportion as these Animals have a less Brain, the Cerebellum is much larger. So that in Fish the Cerebellum is exceeding large, and the Brain very small in proportion to the rest of the Body.

³ The Brain being softer than the Cerebellum, is placed above the latter, and sustained by a Process of the Dura Mater four times thicker than the rest of that Membrane, being separated in the middle by a Process from thence continued and called the Falx.

⁴ By these Cavities the whole Brain may be taken for a Plane convoluted into an Arch intercepting a Part in its middle, from whence all the Nerves arise (§. 272.). In these Cavities are placed the wonderful Plexus Choroides. The anterior Ventricles separate the superior from the inferior Medulla of the Brain; and the third Ventricle in the Medulla itself separates that from the Medulla oblongata. All these Cavities may be more or less filled or emptied with Blood and Humours, so as to render the Brain more free and fit or unfit for its Office.

⁵ These Sinus's are capable of being filled more at one time than at another; for all those Causes which accelerate the Motion of the venal Blood,
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may also occasion a Turgescence of the Sinus's in the Dura Mater, which may again contract themselves by their proper Fibres : but all the Sinus's are placed round the Brain, but none of them round the Cerebellum ; and therefore the Action which results from the different State of the Sinus's is impressed upon the Brain only, where the Secretion and Course of the Spirits may be interrupted without causing any Change in the Cerebellum.

6 Even the Medulla of the Cerebellum arises from its most compact Part, whereas in the Brain, the Nerves arise from the middle of its Cavity ; but in the Cerebellum the Cortex is spread upon the Medulla without intercepting any Cavity or Interval ; for the fourth Ventricle which is a small Notch betwixt the Medulla oblongata and that of the Cerebellum can be of small moment : but from the middle of the investing Cortex the Medulla arises, and by a perpendicular Incision appears like the Branches of a Tree, being at length collected into the four Trunks which are inserted into four distinct Parts of the Medulla oblongata ; and therefore the Cerebellum continues in the same State without Alteration during Life, which the Brain does not. On the contrary, the Brain may be expanded and compressed, or collapse and be relaxed by reason of the Cavities placed in the middle of its Substance, and into which the Blood may be more copiously derived, &c. But any Humour collected in the Cavity of any of the Ventricles in the Brain produces Sleepiness first, and then a Lethargy or Apoplexy ; the like of which cannot take place in the Cerebellum.

7 The Cerebellum is so seated in the bony Case of the Skull, that it is defended above by a most strong Process of the Dura Mater, below by the Occiput, betwixt which on all Sides there is a loose

loose and free Space. The Process of the Dura Mater spread over the Cerebellum is stretched tight like the Parchment of a Drum, so as to re-act against any Force. Externally the Cerebellum is defended by the Occiput, covered in its posterior and lower Part with the *scaleni*, *complexi*, *recti* and oblique Muscles of the Head, so that a Blow or Injury cannot penetrate to the Cerebellum, but through the Brain or through these Muscles.

8 In the Cerebellum there are no Sinus's, only simple Arteries and Veins spread within the Pia Mater and distributed upon the Cerebellum. But the Cerebellum is not invested by the Dura Mater; and therefore the Motion or Circulation of the Humours through the Arteries and Veins in this Part is performed more equably. Add to this, that the Cerebellum receives its Blood principally from the vertebral Arteries, which immediately after their Origin are received into a Canal running through the *Vertebræ* of the Neck on each Side, in which they are secured till they enter into the Cranium; so that they cannot be compressed like the Carotids (§. 232.).

9 I make not the least Doubt but that most Parts of the human Body receive their Nerves from the Brain, but that the Nerves for the Motion of the Heart are derived only from the Cerebellum; and this is confirmed by anatomical Experiments made by the excellent *Du Verney*, who has taught us, 1. That the Brain being destroyed or rendered incapable of its Office, the Heart nevertheless continues to move, which makes it evident that the Motion of the Heart does not depend upon the Brain. 2. On the contrary, the Cerebellum being destroyed or rendered incapable of its Office, the Motion of the Heart is always suppressed; and therefore the Motion of the Heart results not from the Brain but from the Cerebellum:

lum : but since the Cerebellum can supply nothing to the Heart but Nerves, therefore it is evident that the Nerves of the Heart are derived from the Cerebellum. It could never yet indeed be demonstrated anatomically, that any Nerve arises from the Cerebellum only, as the olfactory Nerves are observed to arise only from the Brain : for all the Nerves besides are propagated from the Medulla oblongata, which is formed by the Union of the medullary Peduncles or Footstalks both of the Brain and Cerebellum. But it is sufficient to convince us of this Truth, if we consider that Experiments demonstrate that Injuries of the Brain destroy the voluntary Motions, but do not in the least destroy the Motion of the Heart, which cannot be affected or changed by so slight a Cause as is capable of producing Sleep in the Brain : but when the Cerebellum is injured the Heart itself ceases to move, that is to say, the Animal expires ; for Surgeons well know how much more fatal is an Apoplexy arising from a Compression of the spinal Medulla, than from an Injury of the Brain only.

¹⁰ The Force of the Arteries is nearly equal to that of the Heart, for let but the Heart cease to move by suspending its muscular Force, and the Blood itself will also cease to move, except the Motion derived from the Contraction of the Vessels is increased by the supervening Cold ; whence the Blood is forced from the Extremities towards the right Auricle and Ventricle of the Heart. The Motion of the Blood in the Arteries is continually destroyed, except what is derived from the natural Contraction of the Arteries, by which they protrude the Blood into the less resisting Veins ; which Action of them is likewise increased by the Cold supervening Death. From this Observation we may be able to explain, why in acute Diseases all
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the Blood is found in the Arteries while the Veins appear empty? and why on the contrary in a healthy Person who had been lately strangled or drowned, the Blood is found two or three Days after Death to be all collected in the Veins. while the Arteries are quite empty. Namely, in acute Diseases the Arteries cannot overcome the Resistance of the viscid and congealed Blood, which has been exhausted of its most fluid Parts (§. 260, 261.): But when the Blood retains its fluid State, it is easily propelled by the wonderful Action of the Arteries in sudden Deaths into the less resisting Veins; but the Action of the Lungs ceasing, the Blood cannot pass into the left Ventricle, whence the Arteries will continue to protrude their Blood without receiving their usual Supply; and therefore the Blood will be accumulated chiefly in the large Trunks of the Veins, in the right Auricle and Ventricle of the Heart, and in the pulmonary Artery. If we consider the Motion of the Heart in its natural State, we find that the Blood is propelled from its left Ventricle from no other Cause than a convulsive Spasm or muscular Contraction, the Force of which is sufficient to propel the Blood from the Cavity of its left Ventricle into the Aorta; but this propelling Force is not greater than to dilate the Aorta to such a degree as to give room for the Reception of its expelled Blood (§. 218.). But the moment after this Contraction of the Heart, the Blood contained in its own Vessels being expelled causes that Muscle to look pale and bloodless. But the Blood expelled from the Heart neither stagnates nor is urged beyond the Heart, which being relaxed no longer exerts any Force upon that Fluid. But while the Heart is filling, and before a second Contraction of it follows, all the Blood received from the Heart by
the

the Aorta, is by its contractile Force protruded from its Cavity and Branches into the Veins; so that a like quantity of Blood is conveyed from the Arteries into the Veins in the same time, as the Blood which is thrown from the left Ventricle into the Aorta; whence the Force of the Arteries appears to be equal with that of the Heart, which exerts no other Action but that by which it expels the Blood into the dilated Aorta. But the coronary Arteries which are distributed through the muscular Fabric of the Heart, are empty when that Muscle is in its Contraction; and consequently the instant after this Contraction, the Blood which is propelled every way by the Aorta, will return back towards the Valves and fill the coronary Arteries with the same Force as it is protruded by the Aorta in other Parts. But immediately before the Heart are placed venous Auricles, into which the coronary Veins convey all their Blood. But when the Heart propels its Blood into the Arteries, there is a greater quantity of that Fluid contained in the Cavity of these Veins, and therefore what is redundant flows from the Arteries into the Veins; so that this accessory Force from the coronary Arteries protrudes the venal Blood through the corresponding Veins into the Auricles, from whence the next moment the Blood passes into the relaxed right and left Ventricles. Lastly, when the Ventricles of the Heart propel their contained Blood, that Blood drives forward all the rest contained in the Arteries, namely in the Aorta and pulmonary Artery: and these arterial Trunks being therefore distended at the same time, must necessarily compress the Nerves which pass into the Heart betwixt them (§. 409.) and the Nerves of the Heart being thus compressed during its Contraction, it must necessarily become paralytic

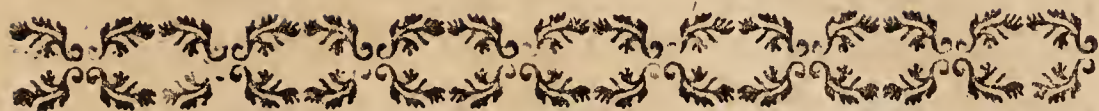
or relaxed in the next instant. But the moment after this Distension of the arterial Trunks, they contract themselves to a less Diameter, whence the cardiac Nerves being set at liberty the Spirits have a free Course into that Muscle. Hence it is that the Heart cannot cease to move even in Sleep; for so soon as the Heart is relaxed, the coronary Arteries are likewise relaxed at the same instant, and therefore the Blood meeting with no Resistance will be freely pressed into them by the Aorta. But at the same time that the coronary Arteries are thus filled and the Ventricles relaxed, the venous Sinus's contract and pour their Blood into the former, while at the same time the Spirits of the Cerebellum flow freely through the Nerves, betwixt the large Arteries which are now contracting themselves. Thus the Heart cannot cease to move, since the three Causes of its Contraction are perpetually renewed, namely, the Repletion of its Cavities with Blood, a free Influx of Spirits by the Nerves, and of Blood by the coronary Articles into its muscular Fabric. But if the coronary Arteries were filled at the same time with the other Arteries of the Body, in that case the Heart would cease to move during the time of Sleep. The beautiful Contrivance of Mechanism demonstrable in this Fabric of the Heart, so much affected the Mind of the celebrated *Pitcairn*, that he pronounced, that if we are ignorant of all other Particulars and could see only the Fabric of the Heart with its Auricles, Sinus's and Arteries, we should plainly perceive, that these Bodies were not made for themselves, but for some other Uses without or distant from them, and that they could not be the Authors of themselves, as *Cartesius* would have us to believe.

Thus

¹¹ Thus indeed it would seem to be with the Spirits of the Cerebellum, since the Vessels of that Part are stronger and thicker than the Vessels of the Brain. But Nature has given every kind of Vessels a different Fluid to be conveyed agreeable to their Texture. It would also seem that the animal Spirits require a longer Preparation than the vital Spirits, since by general Laws of Nature in the human Body, the thinnest Humours are always derived from those which are next in Succession of a more gross Texture. If now it can be demonstrated that the animal Spirits are generated as slow again as the vital, we shall be furnished with a manifest Reason, why the animal Actions cease during one half of Life, when the Heart and natural Powers always continue to perform their Office. For in the first place, there may be a Deficiency of Matter for the Formation of Spirits in the Brain, when at the same time the Cerebellum may be well enough supplied. Secondly, the more sensible Spirits of the Brain may be affected and exhausted, while the more permanent Spirits of the Cerebellum continue undisturbed.

¹² Why these involuntary Muscles do not cease to act during the time of Sleep, namely, those which carry on the peristaltic Motion, I must confess myself ignorant, and resolve the Cause into the Omnipotent Power of the Creator, who has thus wonderfully formed our whole Body at once. Our mechanical Learning teaches us to explain the Nature and Action of Machines, which have been made by a successive Addition of Parts. But a Machine which is produced at once and the same instant of time, cannot be perfectly explained by those mechanical Rules, which are scarce sufficient to acquaint us with the Nature of artificial, and much less with the Nature of created Engines.

But nevertheless these Motions, which we are not able to explain, do really exist in the Body. I have often seen the Stomach and Intestines taken out of a living Animal creep in my Hand after they were extracted from the Body, continuing to move as if they still remained in their Situations. If the Thorax of a living Dog is instantly opened by a sharp Scalpel, and the Heart suddenly cut out, upon throwing it into a Bason full of cold Water, it will jump out so the same as if it was a living Animal, and continue to beat more languidly for a long time after. The Heart being taken out of a large Eel, will continue its Motion of contracting and dilating for several whole Hours together; and even when it stops it may be again excited into Motion by pouring on warm Water. From hence therefore it is evident, that it is not in the Power of human Intellect to explain all things at once, nor even to explain any thing but by Parts, the Glory of which is to be ascribed only to that Being who made all things at once. The Lungs which continue idle in the Fœtus, were nevertheless created and disposed in the same manner as they afterwards appear to us, that they might dilate and take in the Air at the first moment of Life; and that the Lungs and other Parts should be thus formed in the first Delineation of the human Body, before the Action could follow from the Fabric, must be altogether the Contrivance of the Omnipotent Hand. The same is also true with respect to the Foramen ovale, the Canalis arteriosus and venosus, with the umbilical Arteries and Veins, the Urachus, and other Parts.



Of RESPIRATION. ¹

§. 601. **W**HAT Respiration ^{is, or} ~~is, or~~ how it is performed, and why it *continues* ² without the Influence of the Mind, will be evident from what follows; for the Order of our System requires us in the next place to examine into this Action, which although we see performed more than any other, is nevertheless difficult ^{to} ~~to~~ understand; chiefly because it is an Action *partly* ³ vital or spontaneous and partly voluntary, and in some measure because of the *numerous* ⁴ Organs which are employed in the Exercise of this Function; which we are therefore to divestigate with Care and Attention, as may be best done by considering its several Appearances and Organs.

¹ Respiration is an alternate Entrance and Expulsion of the ambient Air into and from the Lungs, by the Wind-pipe and Air-vessels of that Viscus; in which Action we distinguish four Periods: The first is a Derivation of the Air into the expanded Air-vessels of the Lungs, namely, into the Larynx, Wind-pipe or Trachea, and its Ramifications the Bronchia, with their Expansions, the Vesicles of *Malpighi*; Secondly, a Retention of the Air derived into these Receptacles, in which it continues some time without being either inspired or expired; Thirdly, the Expulsion of the inspi-

red and retained Air, from its several forementioned Receptacles in the Lungs: Fourthly, a secondary Rest of the Lungs after Expiration, in which, they continue quiescent for some time without inspiring or expiring.

² This is a difficult Question, not solved by any Physician or Philosopher, until Dr. *Havers* first laid a Foundation for its Solution, by shewing that the Cartilages change their Angles with the Ribs, whose Extremities likewise recede from each other; whence he demonstrates that the breadth of the Thorax is increased laterally. But even at present this Action is not sufficiently understood among ourselves, notwithstanding the numerous Experiments which have been made for that Purpose.

³ That Respiration is a vital Action, appears from its Continuance in Sleep and in Apoplexies, in which it is rather increased, though all the animal Actions are removed. But it is also evidently, in part, an animal Action, because we can accelerate and retard it at pleasure, or take a deep or a short Respiration as we please. But we cannot thus exercise the Influence of our Will upon the Heart, which neither moves slower nor faster according to our Inclination; yet are we only to understand this so as that we cannot immediately by our Will alter the Motion of the Heart; for when we alter Respiration by our Will, either by accelerating or retarding the same, we can by that means also either accelerate or retard the Motion of the Heart as we please. Even in Respiration we must confess that the animal rather exceeds the vital Power; since a Man can kill or strangle himself only by a voluntary Retention of the Air. Thus the Slaves of *Angola* from the southern Parts of *Africa*, being weary of their Lives, retain their Breath as they stand, until they are suffocated; whence

whence we learn, that these Slaves are a precarious Merchandise, since at the least Distaste they deprive themselves of their Breath, and their Master of his Profit.—There are even Instances of Children suffocated by crying, insomuch that it is a common Phrase, for a Child to cry itself to death; and there are again other Instances of People to be found in Authors, who have been suffocated by Laughter. I once saw the Respiration so much obstructed by a profuse Laughter, that the jugular Veins swelled greatly, the Brain and Cerebellum itself beginning to be over-charged with Blood, which if continued might have induced an Apoplexy and Death.

4 Almost an infinite Number of Organs conspire towards the Act of Respiration, each of which ought to be a sound or natural State for the due Continuance of that Function; even there is hardly the least Part of the Body which has not some relation to, or influence upon these Organs. Hitherto belong the threefold vascular System of the Lungs, of which its whole Substance is composed, namely, the pulmonary Arteries, which are as it were a Continuation of the right Ventricle of the Heart; the pulmonary Veins, which are in a manner a Production of the left Ventricle of the Heart; lastly, the Air-vessels of the Lungs, namely, the cartilaginous Bronchia, and their Expansions or Vesicles. To these add the Thorax, Diaphragm, Abdomen and its Muscles, the intercostal Muscles, the Ribs and their firm but moveable Articulations; with the Vertebrae, the Sternum and Clavicles, duly situated. But besides these, to voluntary Respiration belong the Musculus serratus posticus superior, the Subclavius, the Serratus posticus inferior, Rhomboides, and every one of the Muscles moving the Scapula and Ribs; to which add the Flexors of the Neck,

which come into the Assistance of the former. From this Multiplicity of the Organs, it is evident why so few understand the Business of Respiration; for most Physicians can hardly enumerate the Names of those Muscles which are subservient to this Action; but we know of no other Cause of any Action, besides the Parts themselves of the human Body, by which the Action is performed, the Fabric of which being unknown, it is not possible for one to understand their Action. The Clown knows as well as the most expert Anatomist, that in Respiration the Thorax is dilated, and the Abdomen swelled out; but it is the Business of the Physician to know what are the Parts of the human Body which perform these Motions, which being duly performed make Health, and which being injured constitute Disease. The greatest Difficulty in the Knowledge of Diseases results from the Multiplicity of Organs which concur towards any Action or Function, the whole of which is disturbed from the Injury of any one particular Part; whence in the mean time it is very difficult to know precisely, which of the numerous Organs only are injured. If there are a thousand Causes concurring to produce any Functions, and you are unacquainted with but one of them, you cannot be said to perfectly understand that Function; nor yet can you restore the lost Health, if that Cause only of which you are ignorant should be in fault.

§. 602. The Lungs being suspended in the open Air, which has free Access to them on all Sides, and presses upon them every way *equally*, in that case they always collapse and contract themselves into a less Space, becoming much smaller in Bulk than they were, while

while they remained entire in the Thorax ; this we are taught from Anatomy : but this Change is produced chiefly by the Action of the contractile muscular Fibres, which connect the squamose Segments of the Bronchia to each other.

Pressing equally as much upon their internal as upon their external Surface. This Experiment may be easily tried in the Body of a Person, extinguished in Health by sudden Death : First remove the Integuments and intercostal Muscles, being careful to avoid wounding the Pleura ; and then by applying a Candle, you will see through the entire Pleura, that the Cavity of the Thorax is less than is commonly believed, being entirely filled with the Lungs, in such a manner that there is not any Air betwixt the Lungs and the Pleura. Since therefore in this State of the Parts, the Air cannot enter into the Cavity of the Thorax, it will be at rest, and by its Weight press the Thorax as well as the Abdomen against the Lungs, until the Diaphragm ascends up to a Line drawn through the middle of the Papillæ of the Breasts. In the next place suddenly perforate the Pleura, and the Air will immediately and continually enter, whence the Lungs on the perforated Side of the Thorax will collapse. The Cause of its Collapsion is this : The Air being admitted through the Wound of the Pleura, is of the same Density with that admitted into the Cavity of the Lungs by the Mouth, whence the Lungs will be in Equilibrio betwixt the internal Air with which they are filled, and the external Air of the Atmosphere, which presses upon the Thorax without. The Air therefore admitted through the Wound of the Thorax is very improperly said to have compressed the Lungs by its Weight ; for we know from Hydrostatics, that

that every Solid immersed in an homogeneous Fluid, receives no Alteration in its Figure; but in the present Case it is manifest, that the Air admitted into the Bronchia resists, so as to prevent the Vesicles from collapsing, with the same Force with which they are compressed by the Air without. The Cause then of the Collapsion of the Lungs is this, namely, in a sound Body, they are always in a State of Violence, being more expanded by the Air admitted through the Glottis, than they would be, if they were suspended out of the Thorax in the open Air; for the Lungs when in Equilibrio are one third Part less than the Cavity of the Thorax, to which they are equal in the living Animal, and than which they are even larger in a State of Inspiration; since they burst forth thro' a Wound of the Thorax. Therefore the Musculi mesochondriaci or muscular Fibres which connect the cartilaginous Segments of the Bronchia, are always endeavouring to contract the Lungs into a less compass, so soon as the Air is freely admitted to their external Surface, so as to cause an Equilibrium betwixt their distending the Lungs internally, and that compressing them externally; for then the Lungs being set at liberty from their expanding Force, are contracted into a less compass, by the Action of the Musculi mesochondriaci. The Cartilages of the Trachea we know are imperfect or membranous behind; and we also know, that the Bronchia and their Ramifications are made up of cartilaginous Rings, connected to each other by whitish muscular Fibres; which Fibres suffer themselves to be expanded by the Powers which dilate the Thorax and Lungs, by which means the expanded Branches of the Bronchia are elongated; but when that dilating Power of the Thorax ceases, those muscular Fibres by their contractile Force, draw the cartilaginous Segments of the Bronchia towards

towards each other, whence they become shorter, and consequently the Lungs contract themselves by their own proper Force, that is, by the Action of these Musculi mesochondriaci. Hence it follows, that Respiration is not properly performed by any Action of the Lungs, which are themselves passive. They are not the Cause of Inspiration, since they can exert no other Power than that of contracting themselves: Nor are they the Cause of Expiration, for the Force of the Air rushing through the Glottis into the Lungs, is the same with the Pressure of a Column of Water of thirty-three Feet; but so great a Pressure or Weight could not be removed by the Contraction only of the Musculi mesochondriaci. Since therefore the Lungs are perpetually sustained in a sort of Vacuum during the Life of the Animal, they will continually yield to the Pressure of the incumbent Column of Air; that is, they will be perpetually in a State of Inspiration, unless there is an alternate Action of the Causes which produce Expiration.

§. 603. If the Lungs thus contracted (§. 602.) are *forcibly* ¹ *filled* ² with Air, inflated by the Glottis, they will be distended so far as to equal the Magnitude which they had in the entire Thorax, and may be even forced to much exceed that Bulk, as we are taught by Experiments.

¹ This distending Force may be determined mathematically thus: Let a Bladder full of Air be fastened to the Glottis of a living Animal, and let the Bladder be pressed by Weights gradually increased, until the Lungs arrive at a Distension equal to that which they possess in the deepest Respiration, namely, until the Diaphragm is thrust down so low as to form a Plane, or even a Convexity towards the Cavity of the Abdomen.

² In a living Dog, upon which the Experiment before-mentioned has been performed (§. 602.), let the Ribs be broke, and the Lungs by Inflation at the Larynx may be distended, not only so as to equal, but even to exceed the Cavity of the Thorax, which they filled during the Life of the Animal; the Lungs therefore may be dilated by a Power applied to the internal Surface of the Lungs, while nothing dilates them externally.

§. 604. The same Distension of the Lungs (§. 603.) may be likewise performed, if the Air which entered through the Glottis be left in the Lungs; and at the same time, that Air or its Pressure is *removed*¹, which comes in contact with the external Surface of the Lungs, as we are taught by the Air-pump of Mr. Boyle.

¹ This Experiment has been frequently repeated, namely, by taking the Lungs of some young living Animal without injuring them, and then insert a Tube furnished with a Stopper into the Wind-pipe, after which place the whole Lungs and Wind-pipe in a hollow Glass of such a Shape, that the Air may be from thence extracted by adapting the same to a Pump, taking care in the mean time to prevent any of the external Air from penetrating into the Cavity of the Glass, except through the Tube fastened to the Lungs. Thus it will be seen that the Lungs continue of the same Dimensions, so long as they are encompassed in the Glass by the atmospherical Air; and that they will be expanded by blowing into them, as they also will be by extracting the Air out of the Cavity of the Glass, by which last Method they may be distended to a much greater degree, than by Inflation with the Mouth.

Mouth. This Experiment may be also tried in another manner with a Glass in the Shape of a Bell, to the Neck of which the Wind-pipe being fastened, and an oiled Bladder expanded and fixed over its Basis, so as to be moveable by a String; then by drawing down the Bladder, the included Lungs will dilate, and upon letting the Bladder loose again, it will by the Air be pressed into the Glass; whence the Lungs will return into their former Dimensions. For when the Bladder is drawn down, the Air filling the Glass is expanded into a greater Space, or becomes rarified, so as to be incapable of resisting the Pressure of the external Air, which will therefore descend through the Tube into the Wind-pipe and Lungs. Hence then there are evidently two Causes which dilate the Lungs. The first is a greater Pressure of the Air, endeavouring to force itself into the Wind-pipe and Lungs, than is resisted by the external Air placed round the Lungs. The second Cause is a sort of Vacuum made between the Lungs and Sides of the Thorax, while at the same time the Air has a free Entrance into the Air-vessels of the Lungs. The first of these Causes does not act till after Death. For Instance, when you open the Wind-pipe of an Animal almost suffocated by drowning in Water, and force Air into the Lungs by a Syringe, in that case the Animal revives; and there is no doubt but the Experiment would succeed in the human Species; whence it follows that the Lungs are passive in Inspiration, as they give way to the Force of the external Air coming through the Glottis. We are furnished with some notable Instances of Children lately suffocated, who have been restored to Life again, after a very strong Man has very forcibly blown Air through their Nostrils; and there may be always hopes of the

Success

Success of this Experiment, when Death has been lately brought on by some Accident; while the Organs remain entire; as for Example, when the Mind has been suppressed by Grief and profuse Crying; and it is highly probable that many might be preserved, who are otherwise lost by Suffocation, if a Tube was inserted into an Opening in the Wind-pipe. But we are even furnished with more surprising Instances of Persons brought to Life again by blowing Wind through the Anus, as we observed under §. 42. N^o. 2. In this Experiment, nothing more is produced, than a Pressure in the Lungs exceeding that of the external Air.—But the other of the two Causes of Respiration is natural, namely, a sort of Vacuum formed by the Dilation of the Thorax, whence the Lungs are expanded.

§. 605. From hence it is evident, that the Lungs always *endeavour* ¹ by their natural Force to contract themselves in every Point into less Dimensions, than those which they possess during the time of their Confinement within the entire Thorax; and hence again they appear to be always in a State of Violence or Distraction during the Life of the Animal; and therefore they collapse and shrink up into a less compass when the whole Animal is included in a *Boylean Vacuum* ².

¹ The Lungs in a living Animal are always more expanded, than they would be if left to themselves in the open Air, whence it follows that during Life they are in a State of Violence, for so we call that State of any Body, which results not from the Nature of the Body itself, but from some other

other Cause existing without the Body ; and on the contrary, we call the natural State that which any Body acquires spontaneously without the Assistance of any other. The Lungs therefore in a living Animal are always larger, or expanded into a greater compass than they would be if the external Air was admitted into the Cavity of the Thorax. This may be easily demonstrated in the dead Body of any Person or other Animal ; for you will perceive the Diaphragm pressed up on all Sides into the Thorax, so as to reduce its Cavity and Bulk of the Lungs into the least compass : but if in this case you perforate the intercostal Muscles, this very small Cavity of the Thorax will of a sudden be greatly increased, and the Lungs will become still smaller, contracting themselves towards the Spine. But in this case nothing more is done but a Restitution of the equable Pressure betwixt the Air entering the Glottis, and that which is now a free Access to the Lungs externally. The Lungs therefore contract themselves into a smaller compass by their own innate Force, after they have been extended into a greater Bulk by the Air which entered through the Wind-pipe. But even the Lungs in a living Animal collapse in the same manner after the external Air is freely admitted into the Cavity of the Thorax ; and therefore it follows, that the Lungs are continually endeavouring to contract themselves into a less compass, and that they never strive to enlarge themselves. But how then are the Lungs filled with that Air, against which they naturally resist and contract themselves ? We know the Pressure of the Atmosphere which impells the Air through the Glottis into the Lungs, is equal to the Pressure of a Column of Water of thirty-two Feet ; but a cubical Foot of Water weighs almost sixty-four Pounds, and therefore the Column

lumn pressing upon the Mouth of the Wind-pipe, exerts a great Weight, which the Musculi meso-chondriaci are not able to resist. But this Weight of the Air is of the last Necessity to preserve Life and Health. For we perish much sooner in a light Air. Hence we may be able to understand the Nature of that Asthma, in which the contractile Force of the Musculi mesochondriaci is increased to double; for in that case the patient is obliged to pant or breathe short, to expedite the Entrance of the Air into the Lungs. But there is another Species of Asthma like this, which results from a Contraction of the Diaphragm.

² That is to say, a glass Vessel from whence all the Air has been extracted within the Power of our Machines; for notwithstanding the Endeavours of our Mechanics, they are not able to procure a perfect Vacuum, but near one thirtieth Part of the Air will remain, whence a Barometer whose bottom Part is open to the Vacuum, always remains suspended at some small Height, at least in my Experiments. In such a Vacuum therefore the Lungs within the Thorax of an Animal, are not able to fill its Cavity, nor expand themselves, but collapse together into a small compass, whence the Animal expires in a short time; yet so that he may be easily revived again upon admitting fresh Air. From hence I infer, that the Lungs are always larger than they would be out of the Thorax, that is, when as great a Pressure is applied to their external Surface by the Atmosphere, as that exerts to expand them internally. The Cause therefore which keeps the Lungs in a State of Violence, is the Air freely admitted through the Glottis into the Bronchia and Vesicles of the Lungs, while on the other hand, they are not compressed by the external Air pressing upon their Surface; nor can they

the atmospherical Air compress the Lungs, while they are confined in the Thorax, because of the Resistance which the Sternum, Spine, and arched Ribs afford by their Connection to each other.

§. 606. For in reality there *is no Air*¹ like that of the Atmosphere, naturally contained in any Part of the Thorax, betwixt the Pleura and the external Membrane of the Lungs throughout their whole Extent; there is therefore nothing to compress the Lungs externally but the Diaphragm; in the mean time the Air being always freely admitted through the Glottis, will be continually present in the Lungs, which will be therefore always a little more extended by the internal Air, than they are *compressed*² by the external Air excluded by the Diaphragm, Ribs, Vertebrae, &c. so that it cannot enter the Thorax, sufficient to produce an *Equilibrium*³.

¹ The Cavity of the Thorax is altogether nothing in the living Animal, nor is there any Cavity naturally existing in the Pericardium; for the Air rushing into the dilatable Lungs, presses them so close to the Pleura, that there is no Space left betwixt the internal Face of that Membrane and the external Surface of the Lungs, either filled with Air or containing nothing; for it cannot be a Vacuum because an empty Space having no Resistance, the Air entering the Wind-pipe and Lungs, would continually urge them close to the Ribs, so as to occupy that Space. But if there is no Vacuity or empty Space in the Thorax, it is still more evident that it contains no Air. *Helmont*

A a

indeed,

indeed, who thinks different from the rest of Mankind, says, the Thorax contains Air, which he will have to be received through the Pores of the Lungs; but we shall all along demonstrate, that there is no such Air contained in the Thorax, and that if any thing interposes betwixt the Lungs and Pleura, it is a moist Vapour transuding thro' each Membrane, and serving to prevent them from drying or concreting to each other, as they always do upon being dry, as we constantly observe where a Pleurisy has been seated; for the Pleura being rendered insperspirable adheres to its contiguous Lungs. Hence therefore there is neither Cavity in the Heart or Pericardium, but the Space which seems to be in these Parts in dead Bodies, is owing to the admitted Air. For since in the living Animal the Lungs fill the whole Cavity of the Thorax, and since the Pericardium contains no elastic Air to hinder their Expansion by the external Air, the Pericardium will be therefore pressed by them against the Heart with so great a Force, that nothing can be left between, except the exhaling Moisture which prevents their Concretion.

² The Ribs are formed into Arches, so as to keep off the Pressure of the external Air from the Pleura, which can therefore act only upon the Diaphragm; but this muscular Partition is connected on all Sides to the Cartilages of the Ribs, before to the Sternum, and behind to the Loins, so that it cannot enter into the Thorax beyond the degree which is permitted by its Connection with the Ribs and Sternum. But the external Air compresses the Abdomen with the same Force with that which is exerted by the internal Air to expand the Lungs; and therefore the Diaphragm must from hence be pressed as much as its Connection will

will permit into the Cavity of the Thorax. This may be more easily understood by considering the Diaphragm as a Bladder, whose Vertex cannot ascend any higher than its Basis permits; but in the Lungs there is always some Air equally elastic and heavy with that of the Atmosphere, whence they will be more dilated than compressed, because the Diaphragm cannot enter the Thorax with the whole Force which is exerted by the Pressure of the Atmosphere upon the Abdomen, whence it cannot equally resist the Air in the Lungs, received into them by the Glottis and Wind-pipe; and this happens, because the Diaphragm is not permitted by its fixed Points to ascend into the Thorax beyond a Line drawn through the Papillæ of the Breasts, in which Part we see that Wounds inflicted at the time of the most violent Expiration, penetrate into the Cavity of the Thorax; and on the other hand, the Descent of the Diaphragm is determined by the Resistance of the Mediastinum, which sustains the Pericardium, and is largely and firmly connected to the Diaphragm.

3 This is somewhat obscure and deserves to be cleared up. The Lungs then left to themselves, are by the ambient Air reduced into a less compass than that which they occupied in the Thorax of the dead Animal; but in a dead Body the Diaphragm is pressed as far into the Thorax as its Connection can possibly permit, because the Air having free access presses it into the Thorax with a great Force, there being at that time no Resistance from the inspired Air; whence it is that in a dead Body the Lungs are always very small, and yet do they contract into a much less compass by admitting the external Air. Even in People who have expired of an Ascites, when the Water filling the Abdomen has pressed the Diaphragm upward, so

as almost to suffocate the Patient ; even in such Bodies the Lungs contract themselves into a much smaller compass, by admitting the external Air through Perforations in the Thorax. The Air therefore pressing upon the Diaphragm cannot urge the Lungs into so small a compass as they contract themselves into in the open Air ; and therefore there cannot be an Equilibrium equally produced betwixt the Powers compressing the Lungs, and the distending Pores of the external Air, entering through the Glottis.

§. 607. This Truth (§. 606.) which is of the utmost Consequence towards the Doctrine of Respiration, is most evidently demonstrated from *Anatomy* ¹ ; from the Production and Increase of the *Fætus* ² in the Womb, as well as from the Growth of the Infant after the Birth ; from inflating the Lungs ; from *Wounds* ³ penetrating the Cavity of the Thorax, either in one or both Sides, causing a Collapsion of the Lungs, and preventing their Dilatation ; but more especially and plainly does it appear from the celebrated Experiments of *Hooke* ⁴ ; as also from inspecting the Diaphragm, while the Thorax remains entire in a dead Body, for the Diaphragm appears hollow towards the Abdomen, being thrust upwards into the Thorax with a great Force ; also because the Air being admitted through a Wound into the Cavity of the Thorax, the Diaphragm is immediately relaxed, collapses downward and recedes from the Thorax, whose Cavity is thus enlarged. Finally, the
Truth

Truth of this is demonstrable to the Eye, though the pellucid Pleura in a living Animal, while the Thorax remains entire, and the other Integuments are removed.

¹ Anatomy demonstrates that no Air is contained in the Thorax, whose Integuments being removed without opening its Cavity, (as may be most commodiously performed in a Rabbet, whose Pleura is very pellucid;) you will then see with the naked Eye that the Pleura comes into contact below with the Diaphragm, laterally with the Lungs; and behind with the Pericardium and Œsophagus. If there was any Air betwixt the Pleura and the Lungs, however small in quantity, it would nevertheless occupy a Space sufficient to separate the Lungs from the Pleura, so as to prevent them from coming into contact. Thus also in a dead Body which has been suffocated or drowned, there never appears any Distance between the Pleura and Lungs, but the Thorax is every where perfectly full.

² There was a time when the Lungs of the Fœtus were no larger than a Grain of Sand; but in a mature Fœtus of nine Months, the Lungs are grown much larger; and yet do not the Lungs of the Fœtus admit any Air before the Birth. This is readily granted by all, and easily demonstrated from the specific Gravity of the Lungs in a Fœtus, which sink in Water; whereas the Lungs of an Adult never sink, nor can they be so far exhausted of Air even by the Pump, as to cause them to sink in Water; hence therefore it follows, that there could be no Air in the Cavity of the Thorax in a Fœtus. Even if Air could enter into the Thorax of a Fœtus, it would be immensely rarified and expanded, for want of being compressed

sed by the circumjacent external Air; nor would it ever permit the external Air to enter into and expand the Lungs, with that Force which we observe at the Birth of the Infant. But after the Birth of the Infant, when it begins to breathe, even then the Air cannot penetrate into the Cavity of the Thorax; since the Lungs will sooner burst than transmit Air through their Substance either by Inflation or the Pump. Add to this, that if the Lungs had Pores sufficient to transmit Air into the Thorax, we should not be capable of inflating them; for we see among Children, that nothing can perplex them more than when some mischievous Lad having punctured a Bladder, they in vain attempt its Inflation. Nor can Air penetrate the Thorax either through the Diaphragm or any other way; for in no Part of the human Body do we meet with atmospherical Air: and therefore it follows that if we can find no Air in the Cavity of the Thorax, either of the Fœtus or of the Infant after Birth, there must consequently be no Air resident betwixt the Lungs and the Pleura.

3 This is an Experiment of *Galen*, who took it from *Herophilus*, who have been also followed by *Vesalius*, all of them making their Experiments upon Hogs. Having tied down this noisy Animal on its Back on a Table, they removed the common Integuments and intercostal Muscles, so as to discover the Membrane of the Pleura, so however as to preserve it entire, but denudating it so far that by the Approach of a Candle, the Lungs might be seen through the pellucid Pleura. In this Condition the Animal, who is otherwise clamorous enough, roars out violently, and the intent Anatomist may see the Lungs and Pleura, together with the Diaphragm, coming together
into

into contract without any immediate Space. But if now the Pleura is perforated with a sharp Scalpel, the Air suddenly rushes with a kind of Noise into the Thorax, so as to compress the Lungs, and stop its Action on that Side, while the Animal continues to breathe with the Lungs contained in the other Side of the Thorax, but as quick again, and with the Loss of half the Strength of the Voice; since the Lungs on the perforated Side of the Thorax are quiescent. If now again the other Side of the Thorax be perforated, then that half of the Lungs will also cease to move, and the Animal instantly dies, from an entire Suppression of the Respiration. In the same manner when in Wounds of the Thorax, the Air passes from one Side to the other, Blood being also extravasated on one Side, in that case the Surgeon making a Paracentesis on the intire Side of the Thorax to discharge the Blood, the Patient unfortunately expires under his Hands, as being deprived of the Use of both Sides of the Lungs. Hence we conclude, that there is no Air naturally contained betwixt the Pleura and the Lungs in a sound Animal; for if there was the least quantity it would compress the Lungs on all Sides in the living Animal, in the same manner as it compresses them after Death, when it has been admitted through a Wound of the Pleura; for certain it is, that the Elasticity of the Air is equal to the Weight of the whole Atmosphere, as we are assured from the Experiments of Mr. Boyle.

4 This is indeed a beautiful Experiment, and well adapted to give a true Insight into the Nature of Respiration: even if we had it in our Power to make such Experiments towards explaining all the other Functions of the Body, we could easily demonstrate and expound each of them;

This industrious, but melancholy Gentleman, laid before the Royal Society met together, a living Dog tied down upon his Back to a Table, after which he opened the Thorax on each Side instantly with one Cut by a sharp Scalpel, and cutting off the Ribs with a Pair of sharp Scissars, the Lungs appeared collapsed and the Animal seemed to be dying. After the Dog seemed to be dead, the Integuments of the Throat were divided, and a Tube inserted into the Wind-pipe, through which, Air being inflated by a Pair of Bellows into the Lungs; the Animal revived; upon continuing to inflate the Lungs, so as to keep them at rest equally distended, the Animal again seemed to be dying; and again, when the Animal was almost dead, by inflating the Lungs with the Bellows, the Dog always revived, opened his Eyes, moved various Muscles, and the Blood then passing thro' the Lungs excited the Heart to move its Contractions. After he had left the Lungs for some time collapsed, the Animal seemed to be dying, and continued to expire though his Lungs were still inflated; but then again he distended the Lungs more swiftly, by renewing the Motion of the Bellows, and by perforating the Lungs with a small Lancet into the Cavity of their Bronchia, the inflated Air continually escaped through the Punctures, and the Dog appeared to revive. In this manner he caused the Animal to be dying, and revived him alternately for twelve times together, keeping him betwixt Life and Death. From this Experiment it is manifest, that the whole Action of the Lungs consists in changing the Magnitude and Figure of the Air-vessels, which being alternately increased and diminished, procure a free Passage to the Blood through the Lungs; which would not be
able

able to pervade this Viscus if they were continually maintained in the same State of Rest by the Air.

§. 608. Since therefore at the time of Inspiration, the Air enters in a *larger Quantity*¹ through the Glottis into the Lungs than before, it will extend them into larger Dimensions (§. 603.), will overcome their natural contractile Force (§. 605.), and consequently in this Action the Lungs will be passive.

¹ Take a Bladder full of Air, in which is fastened a Tube; if now you apply your Lips close to the Tube, closing the Nostrils, you will see the Bladder collapse in proportion as the Air is received out of it into the Lungs; and this quantity of Air may be measured by those cylindric Vessels which are used for Air-pumps. But all this Air continues in the Air-vessels of the Lungs, since the sanguiferous Parts of this Viscus admit no Air; and therefore the more Air is inspired, so much the greater will be the Capacity or Dimensions of the Air-vessels of the Lungs. Now in order to the Performance of this, it is necessary for the Lungs at the time of Inspiration to be either inflated or less pressed, since there is no other Method by which the Lungs can be expanded. But the latter of these is the true manner of Inspiration; for in breathing I do not press the Air into my Lungs, but by dilating the Capacity of the Thorax, I diminish the Resistance or Causes compressing the Thorax. Hence it follows that Respiration is performed by the Power of the Thorax, and not by that of the Lungs; and therefore it now remains for us to explain in what manner the Dilatation of the Thorax is performed.

§. 609. By

§. 609. By observing Inspiration in a *living Person* ¹, more especially in one who is sleeping, we perceive, first, that the Ribs, especially the nine uppermost, *continuing* ² in their Articulations with the *Vertebræ*, and in their Connection with the Cartilages adhering to the Sternum, do rise up with their *arched* ³ Parts towards the *Clavicles* ⁴, in such a manner that their Motion is chiefly to be observed in the middle of the Arch; but the three or four *lowermost* ⁵ Ribs, are at the same time moved downward and a little obliquely outwards, but so that the seventh, eighth, ninth and tenth of the Ribs with their cartilaginous Extremities, are as it were drawn *inward* ⁶. 2. At the time the whole *Abdomen* ⁷ swells visibly by degrees, during the whole Inspiration, and is thrust strongly outwards. 3. At the same instant also the Capacity of the Thorax is increased, as is evident to the *Eye* ⁸, by *measuring it* ⁹ with a String or in a *Bath* ¹⁰, especially by considering the mechanical Figure, Situation, Connection, and Articulation of the Ribs, which are disposed to form the Thorax with great Artifice; concerning which you may consult the Demonstrations of *Borelli* ¹¹.

¹ I have frequently made Observations upon the Respiration of Men and Infants sleeping naked in the Summer-time, and also in lean Dogs sleeping by the Fire-side, whose ribs might be very plainly seen as they moved; for it is better to consider this Action in the time of Sleep, than the vi-
tal

tal Motion herein concerned, may not be disturbed by the animal Motions.

² The ribs remain articulated to the Vertebrae in this Action, because their Ligaments do not permit them to recede; nor yet are they ever separated from the Sternum.

³ They intercept an Arch betwixt that Part which is articulated with the Vertebrae, and their cartilaginous Extremities.

⁴ Towards the Cavicles in Man, but in Dogs they move towards the Axilæ.

⁵ Observe a lean Infant in a profound Sleep, and you will perceive the nine uppermost Ribs arise slowly, strongly and equably upwards; while the lowermost Ribs in some measure descend downward, and obliquely backward or outward from the Diaphragm, which in that Part is very fleshy. All the Ribs therefore do not ascend as is commonly imagined; and for this Reason it is that Nature has made the intercostal Muscles after a different manner; but while the upper Ribs ascend, the lowermost descend; and since at that time the Ribs are thrust outward, so as to recede from the Middle or Center of the Thorax, therefore the Distance betwixt each Rib will be increased, the Thorax will be elongated and its Capacity enlarged.

⁶ The cartilaginous Extremities of these Ribs are thrust inward in the most violent Inspirations, as in those who are dying; for then Nature uses all means to dilate the Thorax, and propel the Blood through the Lungs; for Death cannot take place before the Course of the Blood is interrupted thro' the Lungs from the right Ventricle to the left. In these Agonies therefore the Neck, Scapulæ, Clavicles, Back and Abdomen labour together by their conjunct Powers in a surprising manner, to enlarge the Capacity of the Thorax.

After-

7 After you have expired the Air from your Lungs, take hold of your Waistcoat with your Hand upon the Abdomen, and you will perceive that during Inspiration the Abdomen will swell and force the Cloaths out of your Hand. For at the time of Inspiration the whole Lungs are inflated, the Capacity of the Thorax is dilated, and at the same time the Diaphragm descends towards the Abdomen, whose Cavity is therefore diminished, and its Viscera compressed at that instant.

8 This is an Experiment which I have frequently tried upon myself. At the time of Expiration let a String be carried round the Thorax, and then let the Air be strongly inspired, by which means you will see how much more of the String is required to encompass the dilated Thorax; and that additional Portion of the String will be the Measure determining the Dilatation of the Thorax.

9 In the Hound of that Species which run before the Wind, the Thorax is large, but the Abdomen is as it were cut out, and the more compressed as the Dog is fitter for the Course; and in such a one we may see the Thorax dilate at the time of Inspiration, the Abdomen receiving scarce any Alteration.

10 If you fix yourself to a Beam in a Bath so as to be immoveable, without causing the Water either to ascend or descend with a fluctuating Motion, and then gradually breathe in the Air, the Water will rise proportionably in the Vessel. For as the Bulk of the Thorax is increased by the inspired Air, the Water will be obliged to ascend higher; but will fall again to its former Mark when you have breathed out the Air. By this means the Difference betwixt the two Marks pointed out by the Rise and Fall of the Water will determine the Quantity and Space taken up by the Enlargement
of

of the Thorax ins Inspiration, beyond what obtained in Expiration. But at the same time the Abdomen will swell downward considerably, from the Dilatation of the Thorax and Descent of the Diaphragm.

¹¹ The Ribs seem to be Bodies of no moment, but if you approach near, you will not perceive any one of the twelve, but what corresponds with the rest in Fabric, Direction, Magnitude, the mutual Connection of their cartilaginous Extremities, and their Articulations with the Sternum and Vertebrae. You will find all of them so disposed, that the largest of the Ribs, namely, the eighth and ninth will be in the middle and the most moveable; and thus the Thorax may be wonderfully dilated, since the Ribs are moveable as well upward as downward. But the upper Ribs which are nearest to the Clavicles are less moveable, and the lowermost Ribs have likewise a less Motion in proportion as they are farther distant from the ninth Rib; the lowermost having little or no Motion, serves as a Basis to support the Diaphragm, and prevents it from descending or collapsing, as it is firmly attached to the last Ribs. The eleventh Rib has indeed a little more Motion towards dilating the Thorax, and the more do the Ribs move as they ascend higher to the fourth or fifth counting upwards. One who attentively considers this will readily confess, that all this must be the Contrivance of Divine Wisdom; namely that the Thorax should be capable of moving without changing the particular Fabric of its Parts, as *Bellini* observes. But all this Doctrine has been considered more at large by *Borelli*.

§. 610. But

§. 610. But also in this Action of the Ribs, the *Diaphragm*¹ is changed from its convex or hollow Position, which is before had, and being brought *downward*², it assumes a more plain or flat Figure; and this we are taught from the opening of living Brutes, as also from large Wounds inflicted upon the Abdomen in the human Species; and again, that this Change of Figure in the Diaphragm proceeds from a Contraction of its muscular Fabric, we are taught by anatomically *considering*³ this Part.

¹ The Diaphragm is a Muscle whose fixed Part is all that conical Ellipsis which is made up by the Sternum, Loins, and seven lower Ribs. To the Margin of these Parts the Diaphragm is connected fleshy, having its largest muscular Portions seated behind towards the Vertebrae, being tendinous in its middle, to which in Man, the Pericardium very strongly adheres. But this tendinous Part of the Diaphragm is higher than is commonly supposed, since a Wound inflicted upon the Thorax at the fifth Rib near the Sternum penetrates into the Abdomen. This Part therefore will be drawn down, while the muscular Fibres are contracted, whence the Diaphragm which ascended like an arched Roof into the Thorax, will be changed into an even Plane, so as to compress the Abdomen and thrust it outwards, more or less in proportion to the Strength of the Respiration, and as the Cavity of the Thorax is more dilated. But all the Viscera of the Abdomen are then pressed by this incumbent Force of the Diaphragm against the tense and resisting Peritonæum. You will perhaps

perhaps say that it is from this Contraction of the Diaphragm, that the cartilaginous Extremities of the Ribs are moved downward and outward: but these Ribs are sustained by the *Serrati majores* in such a manner, that the whole Circumference of the Diaphragm descends, while its middle or tendinous Part only remains at rest.

² It is something wonderful that both the Cavity of the Thorax and Abdomen should be enlarged at the time of Inspiration, insomuch that it is impossible for one to dilate the Thorax without enlarging the Abdomen likewise; for if the Abdomen be secured by Bandage, it will cause a difficulty of breathing, and you will be obliged to breathe more frequently to make up the want of large Inspirations. All these Experiments should be tried upon healthy living Animals, for in those which are dying the Convulsions cause great Disturbance.

³ In the Memoirs of the Royal Academy of Sciences for the Year 1729, M. *Senac* has given us a good Figure of the Diaphragm, in which are represented Fibres placed round the Vena cava and Œsophagus, which Fibres seem to constrict those Canals; yet does that Author deduce Consequences opposite from those which ought to follow from the natural Fabric of this Part, affirming, that Inspiration may be performed by the Intercostals only, and that the Air which enters the Thorax is sufficient to depress the Diaphragm.

§. 611. Since therefore there is no other Action concerned in Inspiration than that of dilating the Thorax, it is evident that the Cause thereof must be determined by the Motion of the Ribs and Diaphragm, the Causes of whose Motions we are next to enquire after.

Inspiration

Inspiration then is a Dilatation of the Thorax made by an Alteration of its Figure, from a spreading of the Ribs and an Expansion of the Diaphragm. If now the Lungs continue without being dilated while the Thorax is expanded, as sometimes happens in an Asthma, in that case a slight Vacuum is made in the Cavity of the Thorax, resembling that made by the Air-pump of Mr. Boyle: but the Atmosphere we know presses upon the Lungs with a Force equal to thirty-three cubical Feet of Water; and consequently our Lungs must give way to so great a Pressure, that is, they will be thus dilated. But in a living healthy Person the Lungs are always dilated, and equally distended together with the Thorax without ever forming a Vacuum, and without any Succession of time betwixt the Dilatation of one and the other. When the upper Ribs are elevated the lower ones are pressed backward and downward; and as the Sternum cannot give way inwards, therefore the Thorax will be dilated on all Sides and throughout all its Dimensions.

§. 612. The ten superior Ribs are incurvated or arched Bones, much more depressed in their middle than at their Extremities which rise up; their Heads being armed with two Apophyses or Protuberances covered with Cartilage, are articulated, 1. Into the cartilaginous Cavity of the Vertebrae, fixed backward on the Sides of their Bodies, or in the Body only of the first Vertebrae of the Thorax. 2. They are articulated into a cartilaginous Sinus fixed in the transverse Processes of the Vertebrae; while the seven superior

rior Ribs are also joined to the Sternum by the Interposition of arched cartilaginous Segments very elastic, in an *acute*¹ Angle upwards in the first Rib, almost at a right Angle in the second Rib, and in the other Ribs forming an obtuse Angle with the Sternum, in such a manner that the Angles here formed by the Cartilages and Ribs with the Sternum *upwards*², is the more obtuse as the Ribs are lower ; in other words, the cartilaginous Segments ascending from the Ribs enter the Sternum laterally in such a manner, that the higher the Rib, the more acute or small is the Angle of Insertion, from the Concourse of the upper Part of the Sternum. 3. But the sixth, seventh and eighth Ribs join their cartilaginous Arches bending up to the Sternum uniting with their Extremities, and adhering to each other at the bottom of the Sternum by broad cartilaginous Processes. The two and sometimes three lower Ribs being furnished with only one Apophysis behind, are by that articulated into only one Sinus fixed in the Body of its corresponding Vertebrae ; and their Cartilages being not more compact than Tendons, do not reach the Sternum, but are inserted into and disappear in the Diaphragm and Cartilages of the next Ribs, and from hence they seem to direct, equally sustain, and assist the Motion of the Diaphragm backward and downward.

¹ The Cartilage of the first Rib cannot move its Rib any way but upwards. The Cartilage of the second Rib, which makes a right Angle with the
B b Sternum,

Sternum, gives it a Motion upward, and in some measure downward ; the third moves only downward with a more ample Motion ; and the fourth is still more moveable downward, till the ninth, which is the most moveable.

² Namely, the eight or nine superior Ribs ; for among these there is often some Variation. They have a threefold Articulation, one to the Sternum, another to the Apophyses of the Vertebrae, and a third, which is properly the affixed Point upon which they move as upon a Center, namely, the extreme Apophyses of each Rib, which are articulated by a true Enarthrosis into a Fissure, seated in the two Bodies of the adjacent Vertebrae.

§. 613. The external intercostal *Muscles* ¹ arising from the lower Margins of the superior Ribs, descend obliquely forward, and are inserted into the superior Margins of the next following Ribs throughout the whole Extent of their Margins, both among all the true and the spurious Ribs : but the internal intercostal Muscles arising from the lower Margin of the upper Rib, at a distance from the Sides of the Spine of the Thorax, descend obliquely backwards across the former Muscles, and are inserted into the upper Margin of the Rib next following below, throughout the whole length of the Bone and its Cartilage even to the Sternum.

¹ It is easy to conceive and explain the Motion of the Ribs, as performed by the intercostal Muscles. It was necessary for these Muscles to be disposed in two different Series ; for if Nature had provided only the internal Muscles, they might
indeed

indeed draw the Ribs towards each other, but then in their Action they would return the Ribs outward, so as to deform the Thorax. If the external intercostal Muscles only were provided by Nature, they would in their Action have turned the Ribs inward so as to disturb the Figure of the Thorax; whereas by the present Contrivance of them in different Series, they draw the Ribs together, while at the same time they preserve the Parallelism of them with respect to each other, without bending any of the Ribs so as to injure the Lungs. —But, secondly, if all the Ribs were equally approximated towards each other, the Thorax could not be dilated; and therefore the first Rib is bent in a half-Ellipsis, and so firmly articulated to the Sternum by a very short Cartilage, that it with difficulty moves upward, but not at all downward. The second Rib is still a little more moveable than the first, and the third more flexible than the second, and the fourth still more than the third, down to the seventh, which is the most moveable both upward and downward. When therefore the intercostal Muscles act and draw the Ribs towards each other, the first of them resists without Motion, the second ascends toward the first, the third toward the second, and so each of them following the inferior towards the superior Ribs, whence the whole Thorax is dilated; so that the Figure of the Thorax is not changed whether the Ribs ascend or descend, because each of them are maintained in their due Parallelism. On the other hand, the Sternum cannot be pressed inward, as being supported by and articulated to the cartilaginous Segments of the Ribs.

§. 614. But to the preceding we must add the *subclavian*¹ Muscle, which arising fleshy from the lower half of the Clavicle, where it is joined to the Spine of the Scapula, proceeds obliquely forward, and is inserted into the upper Margin of the first Rib near the Sternum.

¹ The human Lungs are very large; and in general the Lungs are largest in those Animals which are the most active, and which live with much Exercise. Hence there was Danger, lest in violent Inspirations the upper Ribs might be drawn downward, so as to impede the Dilatation of the Thorax. But Man as a most active Animal is furnished with Clavicles, which are two strong Bones articulated each between the Sternum and Processus acromion of the Scapula, so firmly that they cannot be drawn aside any way. These Bones are only to be found in the more active Animals, who have a free motion of their anterior Limbs every way, such as the Bear, Ape, Beaver, Dormouse, Squirrel, Mole, Bat, Frog, &c. whereas other Quadrupeds are destitute of Clavicles, moving their Fore-limbs only forward and backward. From these Clavicles therefore in Man arise Muscles, which descend to the first of the Ribs, which they elevate towards the immoveable Clavicles. Hence it is that in violent Inspirations, the upper Rib is elevated and in a manner suspended, just as if it had a proper intercostal Muscle of its own filling the intermediate Space betwixt itself and the Clavicle. The subclavian Muscle therefore increases the Determination of the intercostal Muscles upward, and occasions the upper Ribs to ascend only.

§. 615. If then these Muscles (§. 613, 614.) contract together, the first Rib is then *fixed*¹ by the Force of the Subclavian, though it is already sufficiently firm by its own Articulation; and then the nine following Ribs are raised upwards and turned *outwards*², especially in the middle of their Arches, but in such a manner that they continue in their equable Parallelism, while in the mean time they depress the cartilaginous Segments which forcibly *resist*³ them; and thus is the Capacity of the Thorax considerably enlarged.

¹ The subclavian Muscle draws the upper Rib towards the Clavicle, sustains it immoveable, and prevents it from being drawn down by the first Series of intercostal Muscles; and thus is the first Circle of the Ribs fixed and secured from descending.

² The human Thorax is formed so as to be narrowest in its upper part, and broadest downward at its bottom; so that the Ribs are disposed as it were in a conical Shape: and the second Rib while it is elevated towards the first, is not raised by itself; but as its most moveable Point is in the middle of its Arch, therefore it will be there most elevated and turned outward, not so as to alter its Figure, but to increase its Diameter. By this means then the Plane will be increased, which perpendicularly intersects the Thorax. Suppose now the Ribs to be more equal Circles, they would then have certainly diminished the Capacity of the Thorax; since a Circle moved round its Diameter either upward or downward, lessens the contained Space, which is largest when the Circle is at rest.

But in the present Case, the first Circle or the first Pair of Ribs are shorter than the second, the second than the third, and so on enlarging to the tenth; and therefore the drawing up of each Rib is a Dilatation of the Space which it contains.

3 This Resistance of the Cartilages is not easily understood, and yet hereupon is founded the whole Business of Expiration: Why then has Nature made the Extremities of the Ribs not bony, but cartilaginous at the Sternum? And why are those Cartilages not articulated to the bony, but to the cartilaginous Part of the Sternum, or at least with the cartilaginous Sinus's of the Sternum? We must observe that a Cartilage is the most elastic of all Parts in the human Body, and therefore after it has been compressed, it powerfully restores itself of its own accord. That the Ribs are truly Springs, *Vesalius* has taught us, from a play-full Experiment of Lads, who when they want a Ball that will fly back powerfully, may make one of the Cartilages of Fish cemented together; for a Sphere of this nature will fly back more than Metal itself. Nature has therefore made the anterior Extremities of the Ribs cartilaginous at their Connection with the Sternum; but these cartilaginous Extremities are not disposed in the same Direction with the Ribs or Sternum, for the Cartilage of the uppermost Rib forms an obtuse Angle with the same Bone, as it forms an acute one with the Sternum. Hence therefore while the Ribs are elevated, their cartilaginous Extremities are pressed and reduced into a smaller compass by the Compressure; whereupon it re-acts or restores itself the more strongly in proportion to the compressive Force, that is, as the Thorax becomes more dilated; and thus all the Force applied to the whole Rib is sustained entirely by the cartilaginous Segment

ment of the same Rib. The Cartilages therefore endeavour to restore themselves during the whole time that the Ribs are elevated. — The Inspiration then of the Air is performed by the conjunct Action of the Subclavian and all the intercostal Muscles ; so that their whole Force terminates in the Cartilages of the Ribs, which being incapable of Elevation from the Angle of Insertion to the Sternum, are nevertheless overcome by the Action of the intercostal Muscles, whose Action the Cartilages therefore return ; that is to say, so soon as the intercostal Muscles cease to act, the Elasticity of the Cartilages depresses the Ribs and restores them to their former Situations.

§. 616. The Diaphragm, before described (§. 86. N^o. 1.) contracting itself into a Plane, does by that means powerfully dilate the Thorax and compress the *Abdomen* ¹, while at the same time it draws the anterior Cartilages of the small Ribs inward towards the Vertebrae, forcing likewise the two lower false Ribs downward, and distending or overpowering the abdominal Muscles (§. 86. N^o. 2.). But when the muscular Fibres of the Diaphragm are relaxed, then the strong elastic Force of the Pericardium and Mediastinum, suddenly pulls the convex Part of the Diaphragm towards the Throat ; being in that Action much assisted by the contractile Force of the Musculi mesochondriaci, belonging to the Trachea and Bronchia of the Lungs ; to which add the Deficiency of Air in the Cavity of the Thorax.

A person is able to force the Abdomen inward, and to expand or thrust it outward, so as to make a great Difference betwixt its Capacity when expanded, and when contracted. This whole Difference proceeds from the Diaphragm, which is on all Sides attached to the false Ribs, and furnished with two strong muscular Crura or Appendices fixed on each Side of the Loins. When the muscular Fibres of the Diaphragm contract all at one Instant, its several curve Lines are reduced to straight ones, whereupon it descends as far as the connected Mediastinum and Diaphragm will permit, even till it has reached the utmost Limits of Inspiration. But in the middle of the Diaphragm there is a tendinous Expansion, which is not concerned in this Action of flattening the Diaphragm, which is performed by the muscular or fleshy Part only, whose chief Seat is upon the Loins; whence it will be drawn downward and towards the Loins. But this Descent of the Diaphragm is resisted by the arched Ribs; and therefore the moveable Ribs will be drawn down by the Diaphragm, while the Thorax is dilated in the Act of Inspiration, because their cartilaginous Extremities are attached to the tendinous Part of the Diaphragm, which is drawn by its muscular Part. But this Action by which the lower Ribs under the Sternum are drawn inward and downward, appears most evident in those who are dying; for then the posterior Part of the Diaphragm, which is most firmly attached to the Loins, act with all its Force. Now the short lowermost Ribs are interwove with the lower and posterior muscular Part of the Diaphragm; while at the same time into these Ribs is inserted the *Serratus posticus inferior* Muscle, which draws those Ribs outward and backward, and prevents them from being forced too much inward by the Diaphragm:

phragm: and in like manner also the Serratus p^osticus superior in a more transverse Position secures the upper Rib; and in this manner is Inspiration performed.

§. 617. These then seem to be the *only*¹ Muscles employed towards Inspiration; the Intercostals receiving their *Nerves*² from those of the Back, but the Diaphragm receives its Nerves from the vertebral diaphragmatic and intercostal Nerves.

¹ By attentively observing a naked Person sleeping in the Summer-time, you will perceive no Motion either in the Neck, Shoulders, or Arms, only the Thorax will be gently moved upward, and afterwards returned down again. At that time of breathing therefore, these Muscles only act which move the Ribs, while the rest are quiescent. The same is also observable in apoplectic Patients, who have all the voluntary Motions absent, the Organs of those Motions being then paralytic.

² These Nerves probably arise from the Cerebellum, or rather from that Part of the Medulla oblongata, which we now call the Spinalis, receiving its Nerves mixed with those of the Cerebellum.

§. 618. The Capacity of the Thorax being thus enlarged, *nothing*¹ will compress the Lungs betwixt the Pleura and their Surface, and therefore the Air will enter through the Glottis and *inflate*² them, so as to bring them, or rather maintain them in *close*³ Contact with the Pleura and *Diaphragm*⁴ (§. 604.); and
by

by this means will be produced all those Consequences mentioned before (§. 197, to 200. N^o. 2.).

1 The Thorax indeed cannot be compressed, but the Lungs are pressed against the Pleura with the whole Weight of the Atmosphere; so that the Pleura does not compress the Lungs, since it is entirely fastened to the Ribs, and receives itself the Pressure of the Lungs.

2 This is demonstrated by Experiments made with the Air-pump, by which we see the Air rush with a great Impetus, so soon as a Passage is given for it to enter into a void Space; for into such a Space the Air rushes a thousand times more swiftly than the strongest Wind.

3 There are some who believe a *Boylean Vacuum* to be formed betwixt the Pleura and the Lungs at the time of Inspiration, supposing the Lungs to be moved in that Vacuum; but this is a mistaken Opinion, as we observed before (§. 607.); for the Lungs are pressed against the Pleura by the whole Weight of the incumbent Atmosphere, and while the Thorax is dilated, the Lungs are in the same instant expanded, without ever receding from the Pleura. Lastly, the Lungs are never at rest throughout the whole Course of Inspiration, but are from the first to the last instant continually increasing the Dimensions of their Air-vessels, and diminishing the mutual Contacts of their other Vessels: for as we observed before (§. 200.) the Blood-vessels are disposed betwixt the Vesicles, so that these Intervals being increased they will be less pressed, and consequently the Lungs will receive so much more Blood from the Heart, in proportion as there is a less Resistance in their Vessels.

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4 The lower Part of the Lungs, which is compared to the Hoof of an Ox with respect to its Figure, follows the Motion of the Diaphragm; and therefore their Expansion will be here greatest, and the Circulation of their Blood swiftest.

§. 619. In *this State* ¹ of the Lungs and Thorax (§. 618.), the Air acts with an equable Force upon every Part of the Lungs, and being resisted by the Thorax, the Lungs rest or cease to be any farther expanded; now then less Blood will pass through them, a less quantity will be moved into the left Ventricle of the Heart, and hence less will be sent to the Cerebellum and its Nerves; to which add, that less arterial Blood will be impelled into the Diaphragm and intercostal Muscles; so that thus the Causes dilating the Thorax will be weakened, whereupon the Elasticity of the cartilaginous Extremities of the Ribs will depress those Bones, being assisted by the muscular *Fibres* ² which arise from the Sides and bony Ends of the Sternum within the Thorax, and are inserted into the Cartilages of the true Ribs; at the same time also the Fibres of the distended Peritonæum and abdominal Muscles will restore themselves, and by pressing upon the contained Viscera will thrust the Diaphragm now relaxed up into the Thorax; hence then the Thorax will be lessened or compressed, and the Air forced out from the Lungs, which we call Expiration; after this again every thing succeeds as before-mentioned (§. 618.), and,
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by these two Actions (§. 618, 619.) chiefly the Blood is accelerated and moved through the Lungs.

When Inspiration has arrived to its greatest Extent, that is, when the Thorax dilates no farther, then the Lungs cease to move, and no longer receive any change in their Figure. For as the Thorax is now supposed to be at rest, so must likewise the Lungs, which are on all Sides in contact with the quiescent Thorax. But as the Lungs now rest, they no longer forward the Passage of the Blood through their sanguiferous Vessels; so that they do not now act as Lungs, but are of the same Nature with any other Viscus. But we demonstrated before (§. 208.) that the Mass of Blood passes through the Lungs in the same time that it circulates through all the rest of the Body; and therefore so soon as the Lungs cease to transmit freely the Blood, the right Ventricle of the Heart will then begin to be incapable of transmitting its Blood through the Lungs: hereupon the Blood will be accumulated in the pulmonary Artery, while the pulmonary Vein will be empty, and consequently the left Ventricle will receive less Blood, whence the Pressure of the Blood upon the Brain and Cerebellum will be diminished, whence the Secretion of nervous Juice will be lessened, and the Cerebellum rendered incapable of transmitting a due Portion of Spirits to the intercostal Muscles and diaphragmatic Nerves. But we know that every Muscle acts only so far as it is inflated with Spirits by the Nerves; and therefore the intercostal Muscles and Diaphragm will be rendered paralytic or relaxed. But the Ribs drawn up by the intercostal Muscles and compressing their cartilaginous Extremities, will by the Elasticity

sticity of those Cartilages be depressed to their former Situations, so soon as the intercostal Muscles cease to act; since those Muscles overpowerd the Elasticity of the Cartilages only without destroying the same. These Muscles then ceasing to act, the elastic Cartilages will depress the Ribs, and these again will press out the Air from the Lungs, and force their Blood towards the left Ventricle; so that the Blood now flowing more freely and copiously to the Cerebellum, the necessary quantity of Spirits and Strength will return again by the Nerves to the Diaphragm and intercostal Muscles, whence a Repetition of the several Appearances before-mentioned.

² These muscular Fibres seem to retain the Ribs in their Situations; and a Weakness in these renders the Thorax sharp, as we observe in the Rickets. It is these Fibres that make *Musculus triangularis Sterni*, as they are called by *Cowper*.

§. 620. At this Instant (§. 619.) the Blood being accelerated in its Motion, will begin to flow more strongly and plentifully to the Cerebellum and respirative Muscles, and consequently these Causes will be renewed which actuate and contract the Diaphragm and intercostal Muscles, whence the Inspiration will be again renewed; and thus have we assigned the true, immediate and sufficient Causes or Reasons of this alternate vital Motion.

At this Instant the Lungs being compressed by the Thorax and Diaphragm, their venal Blood will be urged towards the left Ventricle of the Heart, which being more copiously filled, will send a greater quantity to the Brain, Cerebellum,
and

and Muscles of Inspiration, which last will be therefore put in Action, and consequently Inspiration will return again. Hence we learn that Expiration is the State of Death; that is to say, the last Action in dying People is an Expulsion of Air from the Lungs by the retorting Force of the Cartilages, which are now become rigid with the Cold, and by that means exert their Elasticity more powerfully.

§. 621. But besides these vital Causes of Respiration, there are others subservient to the *Will*¹, which are likewise applied to the Ribs, in order more powerfully to dilate and contract the Thorax. Those which serve to dilate the Thorax, though designed for *other Purposes*², have nevertheless a share in this Action, when they are determined thereto by the Will. The first of these Muscles is the *Scalenus primus*, arising fleshy from the anterior Part of the transverse Processes of the second, third and fourth Vertebrae of the *Neck*³, and descending obliquely forwards, is inserted with its Tendon into the first Rib. In the next place the *Scalenus secundus*, arising fleshy from the Sides of the transverse Processes of the second, third and fourth Vertebrae of the Neck, descends, and becoming tendinous passes over the former, to its Insertion into the second and also the third Rib. Next the *Scalenus tertius*, arising fleshy from the anterior and lateral Part of the transverse Processes of the second, third, fourth, fifth, and sixth of the Vertebrae of the Neck, is inserted generally
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into the first Rib. By these Muscles therefore the three superior Ribs may be fixed, sustained and elevated, that the Force of the intercostal and other Muscles may not depress them in violent Inspirations; nor is it any Objection to this, that they serve to bend the Neck or turn it round, because if they act together in company with the Spinalis colli, the Transversales colli, Interspinales colli, Longissimus dorsi, and Semi-spinatus fixing or erecting the Neck, while the scaleni Muscles act, these Scaleni must then elevate the Ribs of necessity; but that many of these Muscles concur to dilate the Thorax in the most violent Respiration, is in a manner more than certain.

4. The *Serratus* 4 anticus minor, arising fleshy from the Processus coracoides of the Scapula, and descending obliquely forward, becomes broad, thin and fleshy, and is inserted into the anterior bony Part of the second, third, fourth and fifth Ribs. 5. The *Serratus* anticus major, arising fleshy from the Basis of the Scapula, and becoming thick and broad as it descends obliquely forward, is inserted as it were by indented fleshy Portions into the eight superior Ribs; two, three, four, or five of which fleshy Indentations intercept the like Indentations of the obliquus externus Muscle of the Abdomen. For if the Muscles of the Scapula, the Trapezius, the Rhomboides, and Levator, fix and draw the Scapula upward and backward, retaining it immoveable, then the Ribs from the second to the eighth will be strongly

strongly elevated by the Action of both the Serrati, as we plainly perceive to happen in the most violent Inspirations. 6. Backward the Serratus posticus superior arising tendinous from the Spines of the two lower Vertebrae of the Neck, and three superior Vertebrae of the Thorax, is inserted by fleshy Indentations into the Curvatures of the second, third, and fourth Ribs, which are by this Muscle raised obliquely upward. 7. To these add the Serratus posticus inferior, which arising from the Spines of the Vertebrae of the Loins, and sometimes also of the Thorax, is inserted by muscular Indentations almost into the middle of the Arch of the ninth, tenth, and eleventh Rib, as also into the Extremity of the twelfth; for this last ascending upwards, almost from an horizontal Course with its Fibres, draws these last Ribs outward, downward and backward, so as to enlarge the Thorax, and prevent its Capacity from being diminished by the Approximation of these Ribs, by the Contraction of the Fibres of the Diaphragm.

† We have hitherto explained those Powers which carry on the vital Respiration continuing in the time of Sleep; it now remains for us to explain the voluntary Actions which we experience to be employed in Respiration; for we are able to accelerate Respiration at pleasure, and render it much larger than natural. According to the common Course of Nature, a healthy Person performs one Respiration within the Space of six or seven Seconds at most; but then the same Person may so accelerate his Respiration, as to finish it within the Space of one Second. There

² There was a certain learned Friend of mine, who endeavoured to prove that those Muscles which were not placed betwixt the Intervals of the Ribs, were not employed in Inspiration; but it ought to be considered that every Muscle which is attached to any of the Ribs, is not fastened to a Part absolutely immoveable; and therefore every Muscle adhering to the Ribs may draw them according to their Direction, and the reciprocal Mobility of each towards some other Part, into which the other End of the Muscle is inserted; which other Part if it is more moveable than the Ribs, will be drawn towards the latter by the same Muscle. When the Serrati antici Muscles act, then the whole Scapula and Arm is by them drawn towards the Breast, because the fixed or least moveable Point of those Muscles is in the Ribs, the Scapula being more easily moveable; but when the Scapula is raised and fixed by the Action of other Muscles, in that case, the Serrati may in some measure elevate the Ribs. Even let us suppose the Ribs to resist with the Force of a hundred, and the Scapula with the Force of one; will it not from thence follow that the Ribs will approach one degree towards the Scapula, as that is drawn a hundred degrees towards the Ribs. Suppose again the Scapula to be elevated and fixed by other Muscles, it is evident, that then the Ribs may move through a greater Space as they ascend towards the Scapula, which being now fixed, the Ribs into which the fleshy Indentations of the serrati Muscles are inserted, being then the moveable Point of those Muscles, while their fixed Point is in the Scapula. From hence it is evident, that the Thorax may be much more powerfully expanded by the Assistance of other Muscles, than it can by the Action of the Intercostals only.

3 We are certain that the *Scaleni Muscles* draw down the Neck towards the Ribs ; but suppose the Neck to be powerfully erected or fixed by the numberless Muscles of the Back, (as we see it may be fixed in Porters, so as to carry two hundred Weight laid upon their Head, without at all bending their Neck, to which add that a Man publicly shews himself, who raises an Iron Anvil by the Hair of his Head) ; that is to say, if the Neck is so fixed that it cannot be bent by the *Scaleni* which now act, it is then certain, that the whole Thorax will be drawn by these Muscles towards the Neck. In the same manner it is evident, that all the voluntary Muscles inserted into the Ribs or detached from them into any other Part, perform a twofold Action ; namely, when the other Parts are relaxed, and are not retained by contrary Powers, those Parts will be then drawn more towards the Ribs than the Ribs towards them : but when these Parts are by other Powers more fixed, in that case the Ribs are obliged to move more towards these Parts, than they towards the Ribs ; but it is well known to Anatomists that the *Subclavian*, *Scaleni*, and *Serrati Muscles* are strong enough to overcome the Resistance of the cartilaginous Segments of the Ribs.

4 These Muscles are truly Antagonists to the oblique descending Muscles of the Abdomen ; and when the *Scapula* is raised by the *Trapezius*, *Rhomboides*, and *Levator Muscles*, then the *Serrati antici* and *postici*, draw the Thorax upward and forward. The *Serrati postici superiores* cannot draw the *Vertebræ* towards the Ribs, and therefore they will move the Ribs outward, backward, and upwards towards the *Vertebræ*, from whence these Muscles arise, and pass almost in a transverse

transverse Position; and at the same time they prevent the three Ribs into which they are inserted, from being drawn inward and downward by the Diaphragm, to which they are attached; and therefore each of the Serrati draw the Ribs from the Center of the Thorax, which is thus much more dilated than it could be by the Power of the intercostal Muscles only. Hence it is that we see in dying People, a labouring in the Shoulders, Neck, and Arms, Nature being then incapable of sufficiently dilating the Thorax by the Action of the intercostal Muscles only, whence she assembles all her Forces, in order to relieve the Anxiety. This laborious Respiration was well observed by *Hippocrates*, who understood it to be a mortal Sign, denoting that the Disease was seated near the Ribs, as a Pleurisy or Peripneumony. It is easy to demonstrate that these additional Forces externally applied to the Ribs to raise them, exert a much greater Power than the Intercostals.

§. 622. But the Action of the external and internal, *oblique*¹ and *recti*² Muscles of the Abdomen (§. 86.) conspiring together, *depress*³ the Ribs and contract the Thorax; while at the same time the lower Serratus anticus Muscle, as is evident from its Connection, resists if it concurs with the Action of the *Sacro-lumbalis*⁴, which is a very complex Muscle and hardly to be described, consisting of a Series of muscular or fleshy Fibres, arising from the transverse Processes of the Vertebrae of the Loins, and from their Spines from whence ascending upwards into the Ribs, they are in-

serted or mixed with the fleshy accessory Muscles proceeding from the Ribs; whence it follows, that the Action of this must greatly assist in violent Expirations, the Abdomen being at the same time compressed by the *transverse Muscles* 5.

¹ We come now to enquire how voluntary Expiration is performed. In order to this we are to conceive the abdominal Muscles subject to the Will; and therefore at the time of Expiration when the Ribs are restored by the Elasticity of their Cartilages (§. 619.) that they voluntarily act and press the Diaphragm into the Thorax. In the next place let us consider the Origin of the obliquus externus Muscle, which being from the Os pubis tendinous, it is expanded round the Abdomen, and at last inserted by fleshy Indentations into the Ribs, betwixt the like Indentations of the Serratus anticus Muscle; from whence you may easily understand that the Serratus and obliquus externus Muscle antagonize each other, and that therefore the latter depresses and draws the Ribs inward, as they are drawn upward and outward by the Serratus.

² The fixed Point of the recti Muscle is at the Os pubis, and their moveable Point at the Ribs, those more especially of them which are the most moveable, as also at the Sternum; these Muscles therefore depress the Ribs, contract the Thorax, and press back the Contents of the Abdomen.

³ The internal oblique Muscle arises from the Margin of the Os ilium, almost as far as the Os pubis, and being inserted tendinous in the Linea alba, it must consequently press the lower Part of the Abdomen strongly inward, when it contracts.

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4 The Sacro-lumbalis Muscle has certain Digitations inserted into the Ribs, which it therefore draws downward and backward.

5 The transverse Muscles of the Abdomen, if a right Line be drawn from where those Muscles arise at the Margin of the Os pubis and ilium to the Ribs, that Line will fall much within or beneath the Convexity of the Abdomen; for no living Creature can press back their Abdomen so far, but that it will project beyond the forementioned Line. If now the Abdomen is pressed back against the Loins, they resist that Action, and the Pelvis being in its own Nature immoveable, it follows that the abdominal Muscles will press with their whole Force upon the Diaphragm; which being at that time paralytic or relaxed, from a Deficiency of the Spirits (§. 619.) will be therefore pressed into the Cavity of the Thorax; so as to compress the Lungs and expel their contained Air as much as possible.

§. 623. In *Women*¹ the Sternum is more flat or depressed, the Clavicles are shaped more in a right Line, and the Thorax is less capacious, flatter before, and the cartilaginous Segments sooner ossify above than below; hence when they breathe, the Sternum rises *upward*² and turns obliquely outward, the whole Thorax seeming as it were to arise; and for this Reason they breathe more freely when the Abdomen is distended.

¹ If you observe a Boy of a Year old and a Girl of the same Age, sleeping in the same Bed, you will perceive that when the Girl breathes the

whole Thorax ascends towards the Throat, whereas in the Boy the Thorax and Clavicles have little Motion. In an adult Man the Thorax is hardly moved in Respiration, whereas in a Woman the whole is drawn upward so as to recede from the Diaphragm; whence it follows that the Man breathes most with his Abdomen, and the Woman with her Thorax. If Nature had not made this Difference in Women, they would have laboured under a Difficulty of breathing during the time of their Gestation, equal to what is suffered by a Man in an Ascites; for in Pregnancy the distended Uterus fills the Abdomen in such a manner, that it can very difficultly move, and therefore Nature has provided a greater Liberty in the Thorax, by rendering it very apt to dilate in the female Sex.

² Hence the Scaleni and flexor Muscles of the Neck in Women, with all the Serrati and subclavian Muscles, are to the Surprise of the Anatomist found stronger than in Men.

§. 624. From hence it appears that the voluntary respirative Muscles are much *larger* and stronger than those subservient to the vital or involuntary Respiration; whence it is that the Power of the former Muscles can increase, diminish, or entirely suppress, both the Expiration and Inspiration; of which Actions the Respiration is compounded.

* If you compare the Muscles enumerated at §. 611, and 613; with the Powers of §. 622, and the Muscles of §. 619, with those of §. 621, you will perceive that the latter are at least three times larger and stronger than the former, and that there-
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fore the voluntary Expiration must exceed the natural Inspiration in the same proportion as to Strength; and again, at the time of Inspiration, the Powers mentioned at §. 621, greatly exceed the Powers of natural Expiration. It is therefore evident we can by the Influence of the Will either suppress, increase, or diminish Respiration; one may be able to inspire voluntarily even when Expiration would naturally follow, and also voluntary Expiration may take place when the vital or natural Inspiration should succeed. All this may be easily understood after having first demonstrated that the voluntary antagonist Muscles are much stronger than the involuntary Muscles of Respiration.

§. 625. From hence we understand that there are not two succeeding Moments of Life in which the Vessels of the Lungs retain the *same Figure* ¹, Capacity and *Action* ².

That there are also some Muscles which act here *without Antagonist* ³, as if they had them; and therefore it appears that the Action of the Fluids moving these Muscles, must be antagonized by the simple Resistance and Elasticity of the *Solids* ⁴.

There is therefore *no Necessity* ⁵ to suppose an alternate Action of the Humours in both Parts to produce their reciprocal Motions; since it will be sufficient if that Action takes place in either of them.

Hence we see that the Influence of the Will is capable of suppressing the Force and Causes of Respiration, though it cannot *directly* ⁶ sup-

press the Force of the Heart, whose moving Powers must be therefore *stronger* ⁷ and more constant or frequently in Action; yet is there a certain *Consent* ⁸ or Relation betwixt the Contraction of the Heart and Number of Respirations; but according to what Rule is a Question.

Hence also we perceive the Necessity of repeated Contractions in the Heart, and of repeated Respiration; but *how long* ⁹ they may be suppressed without Repetition, Life still remaining, continues to be a Question.

We see also why in a Fit of the *Asthma* ¹⁰, Peripneumony, difficulty of breathing, and in the Agonies of Death, the Respiration is performed by the conjunct Action of the voluntary as well as the involuntary Muscles moving the Thorax, in such a manner, that we plainly perceive a *Motion* ¹¹ in the Neck, Shoulders, Breast, lower Ribs, and Back?

Why in a perfect State of Health, the Body being at rest and awake, the Respiration is performed very *slowly* ¹², easily and silently; so that it is hardly perceived, though the Circulation of the Humours through the Lungs is then expedited?

Why the Respiration being accelerated by *Coughing* ¹³ or Sighing, increases the Motion of the Blood through all the Vessels?

Why the first Act of Respiration is *Inspiration* ¹⁴, and the last *Expiration* ¹⁵?

Whence it is that the Heart with its *Auricles* ¹⁶ and *venous Sinus's palpitate* ¹⁷ a long time

time after Respiration has ceased in those who are dying?

And whence it is that an Air exceeding *heavy* ¹⁸, *light* ¹⁹, *moist* ²⁰, *dry* ²¹, *hot* ²², or cold, becomes unfit for continuing the Respiration and Life, which may be also said of the Air which is too much rarified or compressed, or which is confined in a small Compass, without being soon *renewed* ²³.

1 The Lungs are continually changing their Figure from the first Moment of Inspiration to the last Pitch of that Action (§. 200.). All the time of this Action the Thorax is continually dilated, and at the same time also the Lungs are continually expanded close to the Thorax which they never desert, and thus in the Expansion of the Lungs the Air-vessels and Blood-vessels are removed to larger Angles from each other, are set at liberty or enlarged, and more freely disposed to receive the Blood from the right Ventricle of the Heart. For the inspired Air repels the Vesicles from their mutual Contacts, so as to make way for the Reception of the Blood into the Branches of the pulmonary Artery, which being a flexible Canal necessarily changes its Figure in the Elongation; but since it is impossible for it to be distracted equably in every Part of the Lungs, there will be some Parts more contracted than the rest; for if a membranous conical Tube is extended longitudinally in a curved Direction, some Part of it will be always complicated or more pressed together, whence its Figure will be every Moment changing. The same is also true with respect to the Veins. But in Expiration also all the Vessels are every Moment

ment contracted into a less Compass, and consequently changing their Figure. Lastly, the Lungs are at Rest for a small space betwixt Inspiration and Expiration; but the Air at that time received in the Lungs is either retained or else allowed a free Exit through the open Glottis. If it be retained, the Blood being always hotter than the Atmosphere in which we live, will rarify the Air, so as to make it press more forcibly upon the pulmonary Blood-vessels, which Pressure will be more and more increased as the Air is longer retained, whence the Capacity of the Blood-vessels will be diminished. If on the other hand the Air has a free Exit from the Lungs, the latter will every Moment suffer an unequal and tremulous Motion while the rarified Air is expelled. What has been here said concerning the Figure of these Vessels, may be also applied to their Capacity; for when the Lungs are expanded the Arteries are larger, and when they are contracted, the Blood-vessels are every Moment diminished: but this Alteration is alternate and perpetual, and therefore we may safely affirm there are not two Moments of Time, in which either the Blood-vessels or Air-vessels of the Lungs continue in the same State.

² This Action of the Vessels is no more than a Contact and Pressure of their concave Surface against the convex Superficies of the Juices, which being in this Case forced through Canals varying their Figure and Capacity every Moment of Time, it follows also from thence that the Action of the Vessels upon their Humours will not be two Moments alike.

³ Every Muscle during Life is continually distended by the nervous Juice and arterial Blood, so as to be held in a perpetual Conatus or Inclination

nation to draw the moveable Part into which it is inserted towards the more fixed or less moveable Part; and therefore that the Muscle thus inclined to Contraction during Life might not perpetually act, another Muscle was required to incline with an equal Force towards opposite Parts, that is to say, it was necessary to keep one Muscle antagonized or in Equilibrio by another. For Example, Suppose one Tendon is inserted into the Back of the last Joint of a Finger, the Flesh will draw that Tendon so as to keep it continually endeavouring to extend the Finger; but if another Muscle is inserted within the same Bone, continually endeavouring with the same Force to bend the same Finger, in that case it will be neither inflected nor extended, provided the Will makes no Addition to the Power either of the flexor or extensor Muscle, for so long will the Finger be kept in a mean State betwixt Flexion and Extension, the Equality and Contrariety of the Forces in the Muscles destroying their Effect. But suppose now the flexor Muscle to be suddenly paralytic or inactive, while the extensor continues to act with the same Force, in that case the Finger will be suddenly extended, as with a sort of Convulsion; or, on the contrary, it will be in like manner violently inflected, if the extensor is paralytic, while the Action of the flexor remains entire. This then is what we intend by the antagonizing of one Muscle with another. But the Intercostals have no Muscles to antagonize them in this manner, the cartilaginous Segments of the Ribs supplying that Office by their Elasticity, which restores the Ribs to their former Situations, after they have compressed the Cartilages by the Action of the intercostal Muscles, which is no sooner over but
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the Cartilages begin to exert their elastic Force and depress the Ribs. But those Animals which carry their Head in a prone Posture, have the Muscles triangulares sterni much larger within the Thorax, which Muscle arising from the Sternum, is inserted into the Extremities of several of the Ribs and their Cartilages, which it serves to depress, so as to assist their Elasticity and antagonizing Force.

4 Those Muscles which antagonize others, prevent the Action of their Opponents, because they are inflated with Juices; but the intercostal Muscles are opposed by the Elasticity of the Cartilages, which proceeds only from the Force of the Solids, and does not depend upon any Influx of Juices; and therefore it follows, that a determinate Influx or Re-action of the Fluids is not absolutely necessary to antagonize Muscles.

5 This may seem a Paradox to some, because Anatomists usually teach, that every alternate Motion results from an alternate Influx of the Juices, detached sometimes to one Muscle and sometimes to another; and this indeed is true whenever there are Antagonists: but when the Antagonist is a Body re-acting only by the Elasticity of its Solids, in that case this universal Affirmation does not hold true. The Heart and Cerebellum propel their Juices equably into all the Muscles of the Body, which are therefore equally distended. The intercostal Muscles are not filled with a greater Force by the Heart, than any other Muscles, but these Muscles elevate the Ribs which are resisted by the elastic Cartilages, when they become stronger than that Resistance, by a more copious Influx of the nervous Juice; for so long does their Power overcome the Resistance of the Ribs, resulting
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from the elastic Cartilages. But when the Actions of the intercostal Muscles fix the Thorax immovable, all the Vessels of the Lungs are retained in the same Situation, whereupon their Force ceases, and some Part of the nervous Juice flowing to the intercostal Muscles will be deficient; and therefore the elastic Cartilages then depress the Ribs without any Assistance from a nervous Juice. Hence it is evident, that Antagonization may be performed only if a Muscle acts on one Side from an Influx of the nervous Juice, and on the other Side if there is an Elasticity of the Solids.

⁶ We are capable of altering the Respiration without changing the rest of the Body, that is, we can increase, diminish, or suppress it at pleasure; but we cannot thus alter the Action of the Heart without first changing the Condition of the whole Body.

⁷ The Action of the Heart is stronger, inasmuch as it is not obedient to any antagonist Muscle; for the Heart continues to move even after Death, which the Diaphragm and intercostal Muscles do not.

⁸ I have made numerous Experiments in relation to this Consent betwixt the Lungs and Heart, more especially fasting, sitting still under a Calmness or Quietness of Mind, &c. under which Circumstances I have remarked the Number of Pulses made in the Space of an Hour, which in a healthy Person answer to 3600, but in Fevers, they amount to between 6 and 8000. But the Pulse is a Dilatation of the Artery, answering to each Contraction of the Heart; of which if you doubt, apply one Hand to the left Breast, and the other to the carotid Artery, whence you will find that each of them strike the Finger at the same Instant.

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The Number of the Pulse is therefore the Number of Contractions made by the Heart. In the next place attend to the Number of Respirations made in a given time with Moderation or without hurrying, and you will perceive the determinate Space of each Respiration, measured by the Clock to answer to about eight Pulses in a healthy Person. It will be also then easy for you to compute the quantity of Blood in proportion to the Heart and Lungs, which is transmitted from the right to the left Ventricle of the Heart through the Lungs at each Respiration, namely, amounting to about twenty ounces, supposing two ounces propelled by each Systole of the Heart into the Aorta. For betwixt the time of Inspiration and Expiration, the Lungs are once filled and once emptied; and there is a determinate Ratio always obtaining betwixt a perfect Respiration and Pulsation, or betwixt the Systole and Diastole of the Thorax with the Systole and Diastole of the Heart. I have frequently tried these Experiments upon myself, till I have been afraid of carrying them too far. But if the Air be quietly retained in the Lungs, the Pulse will be a little accelerated, but it will be retarded soon after; and even if you persist obstinately in retaining the Air, the Pulse will afterwards be quite imperceptible to the Touch. Therefore when Respiration is diminished, so is likewise the Action of the Heart; but by strong and sudden Respirations the Pulse will be accelerated, and even rendered febrile, only by rendering this alternate Action of Expiration and Inspiration more strong and frequent. It is easy to enumerate the Numbers of the Pulse and Respiration in a given time in an Infant sleeping, when you will perceive a certain Rest after each
full

full Respiration, compounded of Inspiration and Expiration : after this wake the Child, and you will perceive the Pulse and Respiration performed quicker than before ; and therefore the Action of the Heart being increased, so likewise will be that of the Lungs, and the reverse ; whence there is evidently a constant Proportion in the Numbers of Action of the Heart and Lungs.

9 This Question may be answered two ways, according as you demand either how long the Air may be retained while the Glottis is open, or how long while the Glottis is shut ? I have made frequent Experiments of this nature upon healthy People, and have observed many things abstruse relating thereto. I have drawn in a moderate quantity of Air, by retaining which I found that Life could not long be sustained in that State ; for the inspired Air retained by shutting the Glottis, or Nose and Mouth, does not rest, but performs the same Action as if you continued to inspire more Air ; that is to say, it rarifies by Heat, and distends the Air-vessels of the Lungs, so as to resist and expel the Blood. But the Blood expelled from the Lungs is conveyed only to the left Ventricle of the Heart by the pulmonary Vein, while that in the pulmonary Artery stagnates in its smallest Branches, whence for a short time the Pulse becomes accelerated. Thus may Respiration be suppressed for some time without danger of Suffocation, namely, until the Air is so rarified by the Heat of the Blood that it can expand no farther ; for then the venal Part of the Blood being evacuated from the Lungs, while the arterial is not transmitted into the Vein, the left Ventricle of the Heart from thence ceases to be supplied, whereupon the Animal must begin to die, since
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the right Ventricle of the Heart is not sufficient to propel the Blood. In this manner the Slaves of *Angola* often suffocate themselves by retaining their Breath. But it does not follow therefore that no Blood is transmitted through the Lungs while the Breath is retained; for such a Portion of it continues to pass through the Lungs, as their Vessels will transmit without Respiration, and much more Blood passes through the Arteries and Veins of the Lungs at that time, than if the Heart was at rest. But in this case the Lungs transmit no more Blood than what any other Viscus would of the same Bulk in proportion to the rest of the Body; just in the same manner as in the Fœtus, the Lungs receive no more Blood than is proportionable to their less Resistance which they afford with respect to the Blood flowing into the Aorta; but this quantity of Blood passing through the Lungs as in a Fœtus, is too small to maintain Life in the Adult, unless the Foramen ovale and Canalis arteriosus continue open.

¹⁰ Do but observe an asthmatic Patient breathing in the Fit, and remark how he labours with his Shoulders, Neck, Back, &c. in order more largely to dilate the Thorax, and to render the Action of the serrate and scaleni Muscles more powerful.

¹¹ The human Body is so framed by its Creator, as to be always endeavouring to keep in the same State in which he first made it; and hence what *Hippocrates* calls Nature, is the Effect of the Structure of the Parts in the human Body, so framed by its Creator as to continue in the same State so long as its Fabric remains unaltered. Thus therefore has the Creator made the Thorax capable of receiving a stronger Action, in proportion as
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more Blood is to be transmitted through the Lungs in a given time, or in proportion as the Vessels, or the Blood itself, afford a greater Resistance to its Course through the Lungs. If therefore the quantity of Blood is determined, which can be freely transmitted through the Lungs of a healthy Person at Rest, as the Blood in the same Person will be accelerated by Exercise so as to increase the Mass which is to pervade the Lungs, by sending back to the Heart the Blood, which before stagnated in the Veins, in that case there will be twice as much Blood to be transmitted in the same time; or if there is any Cause which gives twice as much Resistance to the Lungs, or to the Blood, in all these Cases the Respiration will be twice as large: and if the Blood is to be transmitted ten times swifter, to supply the left Ventricle with its due quantity in a given time, the Respiration will be ten times quicker; that is to say, the scaleni, serrati, rhomboides, cucullares, and other Muscles, all of them conduce to accelerate and enlarge the Respiration, in order to enable the Lungs to transmit more Blood in the same time. But it is the same thing in effect, whether the quantity of the Blood or the Resistance be increased; for if the Lungs themselves become impervious, more or less the Resistance will be proportionably increased, and the Muscles of Respiration will be obliged to labour more in proportion, as we see in Asthma's from a Scirrhusity of the Glands, an Infarction of the Vesicles, a convulsive Constriction, &c. of the Lungs. Hence when the Blood begins to stagnate and thicken in Death, or in a Peripneumony, the voluntary Muscles of Respiration labour with great Violence, and afford a frightful Spectacle,

that they may enable the Lungs to transmit some Part of the Blood. In such a Person you will see the whole Thorax ascend while the Diaphragm at the same time is drawn violently downward, every Part throughout the whole living Body also conspiring to promote this Action, and to procure some Relief of the Maladies which cause these Agonies.

¹² Among all the Signs of good Health, the principal is a slow Pulse and Respiration, the latter being performed without any visible Motion of the Thorax or Abdomen, and without any audible Noise. For by these Signs we know that the Lungs are most slowly inflated, that they rest and that they empty themselves; but this Slowness demonstrates an equable Motion of the Blood without any Obstruction or Resistance; and that the Blood does not stagnate, thicken, nor meet with any Obstacle to impede the equable Circulation of the Humours through all the Vessels of the Lungs.

¹³ When a Vein has been opened by a Surgeon, the Blood often does not start out, but if you order the Patient to cough, it instantly flies forth in a full Stream. It is therefore evident, that the Course both of the venal and arterial Blood is promoted by the Action of the Lungs, and that their Action is increased by a deep Inspiration and a strong Expiration; but such is that Inspiration, which we call Sighing; and therefore that as well as Coughing must evidently accelerate the Motion of the Blood. In a Pleurisy when the Blood ceases to start out from the Orifice of an open Vein, let the Patient sigh, and the Blood will flow forth swiftly enough; but
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to this Action the Patient will not be inclined, to avoid the Pain, and therefore the Surgeon may order cold Water to be sprinkled on his Face, that the Vessels may contract and forward the Course of the Blood ; or he may administer some warm Wine, or let the Patient smell to some hot Vinegar, whose acid Fumes being drawn into the Lungs, will excite a lasting and strong Cough, which will cause the Blood to flow fast enough. For by Expiration the venal Blood flows more swiftly from the Lungs into the left Ventricle of the Heart, which will therefore propel a greater quantity of Blood into all the Arteries of the Body, and from thence the Veins will receive more Blood from the Arteries.

¹⁴ When the Foetus first comes forth from its Mother's Womb, its Lungs and Thorax do not differ from those of an Adult, except in having the Foramen ovale and Canalis arteriosus. But the same Foetus has no Air at all in the Thorax ; but, on the contrary, there is Water in that Space which some suppose to contain Air. Nor yet does the Air enter the Lungs at the Birth spontaneously or by its own Weight, as I formerly believed with *Pitcairn* and *Baglivi*, but am now convinced of the contrary ; for I have seen that the Lungs of a Foetus after Exclusion are not distended with Air, though the Glottis remains quite open ; and therefore it follows, that the Air enters the Lungs of the Foetus, because its Thorax is dilated by the Muscles proper to Respiration. The first Action therefore of the Foetus or Infant upon coming into the World is to dilate the Thorax, which is afterwards spontaneously contracted so as to cause Expiration, as we before observed. But why does

the Foetus break its including Membranes, that it may breathe? Whether this is done with Design I cannot determine; but this is certain, that the Infant kicks and struggles till it has burst the Membranes and breathed Air, and that after it has once breathed, it remains quiet enough.

¹⁵ To expire or give up one's Soul, is a Phrase synonymous with Death in all the Languages of the World, because this is the last Action of the Body, which is not performed by any vital or voluntary Power in ourselves, but only by that Force which is in common possessed by all other inanimate Bodies. This Action therefore is exerted because the vital Powers cease to act, and the intercostal Muscles becoming paralytic, the cartilaginous Extremities of the Ribs, do by their own Elasticity unbend themselves and depress those Bones.

¹⁶ In a Dog which has been opened alive, the Heart ceases to move, but then a small tremulous Motion continues in its Auricles, which seem to undulate, namely, because the Heart keeps warm longer than any other Part, whence the Auricles continue to evacuate themselves in some measure into the Heart, which is not yet become rigid.

¹⁷ Even this Palpitation is often observed after the Animal is really dead. The human Body has Vessels and Fibres which vital Warmth render very large; for Heat or Warmth equably expand all Bodies throughout their Dimensions: but in a dying Person the Heat gradually departs, until the whole Body acquires the Temperature of the Atmosphere, which is not sufficient to sustain Life in any Animal; but this cooling of the Body in
Death

Death proceeds from without inwards, that is to say, the external Parts in contact with the Air become cold first, while the more interior Parts remain still warm and dilatable. But the Heat of the Body we know is greatest at the Heart; and therefore the Veins contracted by the Cold, will derive the Humours from all Parts of the Body towards the Heart, so as to render it capable of continuing its Motion for some time longer. Hence in those who appear with a red and turgid Face while dying, their Face will look pale and flaccid after they are dead, when the Body is quite cold. But even in such a dead Body, the Heart may be excited to palpitate by injecting Water into the Vena cava; and therefore these Motions in Death arise from the Contraction of the Veins occasioned by the Cold.

¹⁸ A heavy Air presses more upon the Vesicles of the Lungs as it exceeds more in Weight; but in proportion as their Vessels are more pressed, so are the Blood-vessels more compressed. When therefore the Air is as heavy again, the Vessels of the Lungs will be pressed with twice as much Force against the Pleura, whence they will be contracted or lessened, so as to resist the Blood from the right Ventricle of the Heart, and this stronger and stronger, till they at last transmit no Blood at all.

¹⁹ A light Air presses less upon the Vesicles of the Lungs, which are therefore less distended. That is to say, the Lungs continually exert their contractile Force, but remain continually dilated close to the Pleura, because the contractile Force of the Musculi mesochondriaci is less than the distending Force of Air in the Lungs. Let the Air then press upon the Lungs with a Force twice as

weak, and then the Musculi mesochondriaci will be twice as strong, will contract themselves with twice the Power, and act as we see in a spasmodic or convulsive Asthma, so as to suffocate the Patient by a Constriction of the Lungs.

²⁰ A moist Air is so pernicious, because it fills the whole Lungs with inelastic Vapours.

²¹ A dry Air is injurious by crisping up the pulmonary Vessels.

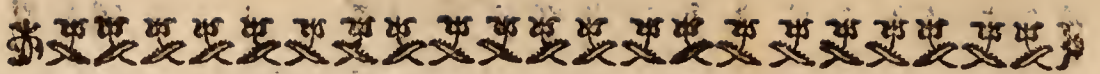
²² A hot Air is always light, but a cold Air has always the Properties of a heavy Air.

²³ This I must confess is very obscure and not easy to be understood. Every Animal or even Vegetable we are assured from a thousand Experiments, will die when included in a small quantity of Air which is not renewed. If you sow good Seeds in the best Earth, and administer the most convenient degree of Warmth which is necessary to raise the Plants in a Vessel full of Air, if you do but stop up that Vessel, so that no Air can enter into it or pass out from it, those Seeds will not grow, and those Plants which vegetated in open Air will here languish and die. Again, place any Animal in a Glass full of the best Air, and do but close the Glass, and you will see the Animal perish in a short time, even if it is but a Fly included in a large glass Sphere, or a Sparrow shut up in a glass Vessel capable of holding a hundred of these Birds. If you place a Thermometer in that Vessel the included Air will appear of the same degree of Heat with that of the Atmosphere, only observe this, that the Air will have lost about $\frac{1}{14}$ Part of its Elasticity which is destroyed by the Animal. Is not that therefore the vital Spirit supposed by the Alchymists to reside in the Air, which
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is consumed by our Breath, and which must be perpetually renewed through the whole System of Beings ? for without it is thus renewed, the Air, say they, having lost its vital Spirit is not sufficient to support Life. This vital Spirit, say they, can be found by none but a true Philosopher ; but no one can demonstrate what this vital Spirit is more than the Elasticity of the Air : But I shall perhaps speak more concerning this in my public Lectures, when I come to treat concerning the Causes of sudden Death.

F I N I S.





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